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JOHN F. KELLY, EDITOR

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Coming Meetings and Papers

ASSOCIATION OF IRON AND STEEL ELECTRICAL ENGINEERS

PHILADELPHIA DISTRICT SECTION

W. H. BURR, Chairman — LINN O. MORROW, Secretary

SATURDAY, NOVEMBER 4, 1933

"WELDED DESIGN," Everett Chapman, Vice President in Charge of Research and Engineering, Lukenweld, Inc., Coatesville, Pa.
A special invitation to attend this meeting is extended to the members of the Philadelphia Section, American Welding Society.

SATURDAY, DECEMBER 2, 1933

"ELECTRICAL DRIVES FOR SHEARS," L. A. Umansky, Industrial Engineering Department, General Electric Company, Schenectady, N. Y

SATURDAY, JANUARY 6, 1934

"DESIGN AND APPLICATION OF GEARMOTORS," R. P. Marthens, Manager of Engineering, Westinghouse Electric & Manufacturing Company, Nuttall Works, Pittsburgh, Pa.

SATURDAY, FEBRUARY 3, 1934

"APPLICATION OF LIGHTNING PROTECTION TO POWER SYSTEMS," B. Van Ness, Jr., Electrical Engineer, and Edwin Hansson, Transmission Engineer, Pennsylvania Water & Power Company, Baltimore, Md.

SATURDAY, MARCH 3, 1934

"INSULATION AND INSULATION LACQUERS FOR CABLES AND COILS," C. F. Hanson, Electrical Engineer, Irvington Varnish & Insulator Company, Irvington, N. J., and E W. Davis, Electrical Engineer, Simplex Wire & Cable Company, Boston, Mass.

SATURDAY, APRIL 7, 1934

"GENERAL IDEAS AND DISCUSSION." Every Active Member is invited to prepare a short paper on a subject pertaining to the application of Electricity to the Iron and Steel Industry.

Some of the papers to be presented are as follows:

"REACTORS VS. RESISTORS IN INDUSTRIAL CONTROL," Fred O. Schnure, Superintendent Electrical Department, Bethlehem Steel Company, Sparrows Point, Md.

"VARIABLE SPEED MOTORS FOR ACCUMULATOR PUMPS," R. F. Gale, Plant Engineer, Midvale Company, Philadelphia, Pa.

"STEAM INDUCED DRAFT VS. FORCED AIR ON HEATING FURNACES," W. N. Horko, Electrical Engineer, Henry Disston & Sons, Philadelphia, Pa.

"REDUCTION OF POWER COSTS BY THE USE OF MODERN EQUIPMENT," George C. Pfeffer, Chief Electrician, Florence Pipe Foundry & Machine Company, Florence, N. J.

All meetings will be held in the Engineers' Club, 1317 Spruce Street, and will start promptly at 7:00 P. M. They will be preceded by an informal dinner at 6:00 P. M.

The privileges of the Engineers' Club are at the disposal of the Members on the date of the meeting. Make the Club your headquarters.

Attend every meeting and bring your friends.

NEW USES FOR STEEL

For some time past the steel industry has endeavored to stimulate trade and thus increase employment by strenuous efforts toward a reduction in the cost of operation, but as such decreased cost usually involved an increase in production the A. I. & S. E. E. conceived the idea of a contest which would bring out "New Uses for Steel" which would assist in utilizing such increased production. To make this effort as successful as possible, no restrictions were placed on the contestants so that suggestions were received from men representing all branches employed in the industry except the Sales Departments.

In order to insure fair competition, forty judges were given only the suggestions, without any knowledge as to their source, and it is gratifying to the Association that the first prize was awarded to one of it's founders, Barton R. Shover, who is also a Past President and who has been active in promoting the interests of the Association.

The second prize was awarded to M. Appel, Draftsman, Ohio Works, Carnegie Steel Company, Youngstown, Ohio, and the third to S. Ein, Testing Engineer, Illinois Steel Company, South Chicago, Illinois.

The following are the three first prize winning suggestions:

Barton R. Shover, Suggestion—Manufacture of bath rooms on a production scale. Hotels and apartment houses each, have many bathrooms which are duplicates, nor are there many types of bathrooms in modern private dwellings. It is suggested that complete bathrooms be assembled in factories and shipped to destinations where they would be placed in position, three pipes and two electric wires connected, and the room ready for use. The room would consist of a steel frame, lined inside wholly or in part with sheet steel, finished in baked enamel, lacquer, or even paint. Floor and as much of the walls as desired could be tiled. Several years ago, one of the large manufacturers of appliances experimented with enameled bath tubs of pressed steel, but found that when the tub was stiff enough to prevent cracking the enamel, no saving resulted. The Briggs Manufacturing Company of Detroit, has recently perfected a stamped steel enamel sink, made from No. 14 gauge sheet. Stamped steel bath tubs and lavatories are promised by the same concern. Should the "weaving" of the light gauge tub tend to crack the enamel, the inside could be chromium plated. Lacquer interior finish would be attractive particularly to apartment houses, because the color scheme could be cheaply changed to suit the ideas of the new tenant. Because each bathroom is now an individual job the labor cost is excessive. Quantity production would greatly reduce this cost and the saving would eventually benefit the purchaser. The most serious difficulty to be overcome in introducing this type of bathroom would be antagonism of the labor unions.

M. Appel, Suggestion—Investigation and research should be made to further the use of decorated steel tile. This tile would consist of thin steel plate coated in various pleasing colors with enamel or paint. The tile would have various shapes, square, rectangular, etc. depending on use. Decorated steel tile could be used in home for wainscoting purposes in kitchen and stairways, for bath room use etc. In public buildings it could be used in schools, restaurants, or any other place where a pleasing sanitary wall covering was needed. Steel tile would stand hard use, could be easily kept in clean condition. Joints between tile could be arranged so that placing of tile on walls would be simple operation.

S. Ein, Suggestion—Telephone Booths Containing Coin-In-Slot Telephones can be made from steel plates as easily as they are being made from wood.

Barton R. Shover, the recipient of first prize, entered the industry in 1895 as a crane inspector, five years after his graduation from Rose Polytechnic Institute, the intervening period having been devoted to street railway and electric lighting construction and operation. In 1898, he rose to the position of Chief Electrician of what is now the Ohio Works of the Carnegie Steel Company. His service in this position merited the advancement he received in 1906, by being chosen to fill the position of Electrical Engineer for the Gary plant of the Indiana Steel Company, which was not only the first completely electrified plant, but also the largest individual industrial installation of electrical equipment in the world. Four years later, he was transferred back to Youngstown to assist in designing and building the McDonald plant of the Carnegie Steel Company.

In 1912, Mr. Shover was appointed General Superintendent of the then newly organized Brier Hill Steel Company, in which position he built and placed in operation their steel works and rolling mills. Two years later he went to India as General Manager of the Tata Iron and Steel Company, and since his return to this country, at the end of 1916, has been continuously engaged in Consulting Engineering, with offices in the Oliver Building, Pittsburgh, Pennsylvania. In 1917, as the result of Mr. Shover's professional record, his Alma Mater conferred upon him the degree of Electrical Engineer. In addition to his long membership in this Association, he is a Fellow of the A. I. E. E. and a member of the A. I. & S. I., and the E. S. of W. Pennsylvania, and has contributed many new ideas and inventions leading to the advancement of the industry.

The award of the First Prize for a factory built bathroom, was merited by the novelty of the suggestion, the possible steel requirements and the resultant saving in the cost of building construction. Those who have observed the construction of hotels, apartment houses and similar buildings, have undoubtedly noted the piles of bath-tubs, wash basins and other plumbing fixtures scattered about the premises. The time required to install this equipment in the small space allotted to it, and the skilled labor necessary for such work results in a large item in building costs.

Since the great majority of bathrooms in any one of such buildings are duplicates, they could be completely assembled in a factory, using the straight line production method so thoroughly developed by the automobile industry. The entire structure is then shipped to it's destination, placed directly in final position, two water supply pipes, one drain pipe and two electric wires connected, thus completing the installation.

The walls of the room could be tiled, enamelled or painted as requested by the purchaser. Lacquer would permit quick and inexpensive refinishing to suit the taste of each new tenant in apartment dwellings. While the assembled room could be equipped with cast-iron or porcelain appurtenances, pressed steel tubs etc., were suggested, as they could be designed with equal sanitary advantages and even better appearance.

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Reduction Gear Sets in Connection With Main Drive Mill Motors

By AUSTIN KUHNS
Mechanical Engineer, Farrel-Birmingham Company, Inc., Buffalo, N. Y.

Presented before the Mechanical Engineering Division of the A. I. & S. E. E. at the Twenty-ninth Convention in Pittsburgh, October 18, 1933.

The acceptance of reduction gear sets as a means of obtaining the most desirable roll speed becomes more natural and logical as progress in motor design advances along the lines of higher speeds and heavier powers. Their importance in the modern steel mill is measured by the reliance which is placed upon them for smooth, uninterrupted and efficient operation.

AUSTIN KUHNS

PART I—JUSTIFICATION FOR GEAR SETS—

Permit Standardized Equipment

Reduction gear units make it possible to use standard motors and control equipment with attendant convenience in the mill installation, and the items of maintenance and spare parts. These advantages accrue, not only to the steel mill owner in the form of savings and simplified construction, but also to the benefit of the electrical and mechanical equipment builder in the terms of lower development and manufacturing costs.

Duplication, standardization, quick and easy replacements or additions, tangible disposal values and similar products of our industrial methods are made available with the use of gearing. Emergency repairs are quickly finished, shut-downs are brief and loss of production noticeably reduced.

Permit Best Motor Speed

With the use of gear drives the speed of the electric motor can be selected as desired. Naturally this will be comparatively high to take advantage of its smaller size, lower weight and initial cost, saving in floor space, cheaper accessory equipment, reduced maintenance, higher mechanical efficiency and improved power factor.

Delivers Desired Mill Speed

The reduction gear set delivers the exact mill speed desired and permits a change in this speed at a reasonable expense. Its use involves no compromises. With individual motors closer control of the respective mill speeds is made possible, and greater freedom and convenience in the layout and the relation of the stands with each other, especially in the continuous mills.

Does Not Incur Large Expense

With few exceptions the savings in motor and equipment more than pay for the gear set. The power consumed through its use is surprisingly small and its expense is justified by the increase in operating efficiency of the entire rolling mill installation.

Efficiency of Gear Sets

Most careful and elaborate tests by scientific institutions have proved that industrial herringbone gears have an efficiency under full load of 99.4%. The power lost through the self-contained reduction unit is greater, due to the friction in the bearings and to the agitation of the lubricating oil. It is difficult and costly to measure these losses and it is impossible to calculate them with our present limited information concerning many of the factors involved. Special tests of small units show an average overall power loss of 1½% with the sleeve bearing design and 1¼% where anti-friction bearings are used, or expressing it in another way, these units have an efficiency of 98.5% and 98.75% respectively, figures which are substantiated by the very large powers which comparatively small gear sets are handling without undue heating.

Special Mill Requirements

Representative of the application of gear sets to special mill requirements is the design which combines the drive with the pinion stand into one integral unit, and which is now used so extensively and effectively. A pinion stand, in all of its characteristics, is a gear set and when coupled with the drive actually becomes a multiple reduction unit. It conserves floor space, costs less to build, is more simple to maintain and more efficient to operate.

The selective speed design has never been fully exploited, although during the past decade its reliable and satisfactory performance has been proven. This type of gear unit delivers the same horsepower at either speed, which is very desirable in certain classes of rolling. Its use, coupled with a multiple speed A.C. motor, produces many selective speeds which, for ordinary mill operation, avoids the need for D.C. current. It is compact and is not expensive to produce, it can be run at high speeds, and is very efficient.

The number of possibilities in arranging multiple spindle gear drives is without limit, especially today with the use of welded steel plate housings which avoid expensive patterns. Gears can be nested to provide power take-offs at almost any desired place and speed. These special designs are fully as reliable as the standardized units.

There is unlimited scope for ingenuity and resourcefulness in the application of such special gearing arrangements. The savings and benefits which can be effected justify the continued study of their possibilities, and the designing engineer should make use of them to the fullest extent.

PART II—PRELIMINARY ENGINEERING

Center Distance

The center distance determines the important dimensions of the gear set, such as the sizes of the gears, the tooth velocity, the tooth pressure, etc. It is fixed frequently by local requirements or desires on the part of the operating personnel. Where complete freedom in its selection exists, it conforms with experience and good judgment. As it becomes larger the tooth velocity and the cost and size of the unit increases. A decrease in center distance introduces higher tooth loads, wider gear faces and lowers the rigidity of the shafts and housing structure.

Velocity

Theoretically the limit to gear speeds is the point where the gear wheel bursts from centrifugal force. Actually gears cannot be run at anything like this speed because no one has been able to attain perfection in their manufacture. Reliable, efficient and successful installations are in use where the tooth velocity is as high as 12,000 f.p.m. Speeds approaching 10,000 f.p.m. are not uncommon in power plant work. In rolling mills 5,000 f.p.m. is the limit today, although there is no reason why this cannot be exceeded to advantage. In the bulk of the mill installations, however, the tooth velocity falls within the range of 1,500 to 3,500 f.p.m.

The many factors which contribute to the success of the gear set are influenced materially by its speed of operation. For convenience the velocity range is divided into zones against which standard tolerances for design and manufacture have been set up.

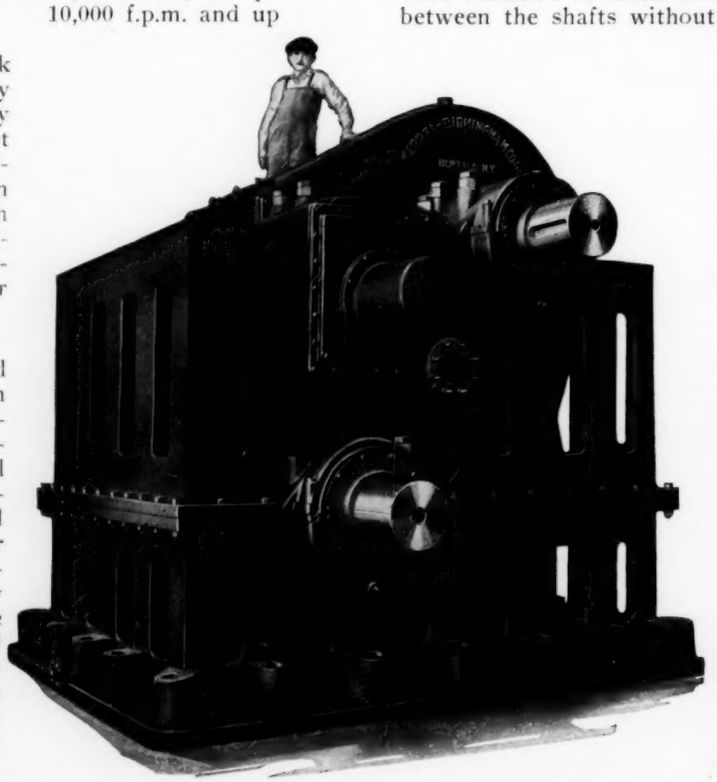
0 to 500 f.p.m.	3,000 to 5,000 f.p.m.
500 to 1,500 f.p.m.	5,000 to 10,000 f.p.m.
1,500 to 3,000 f.p.m.	10,000 f.p.m. and up

Journal Speeds

For industrial work the peripheral velocity of the journals rarely exceeds 2,000 f.p.m., but where this exception occurs special details in design and lubrication are required. This condition holds for antifriction bearings or for sleeve bearings.

Ratio

It is now believed that ratio has not been given enough consideration. The driving pinion has been accepted as the basis for the design and the gear wheel given sufficient diameter to suit the ratio required. In the last few years, however, where high powers and small ratios have been introduced, experience has indicated that special factors are required for these installations — a study which should be projected into the higher ratio designs.



Typical multi-spindle drive for steel mill service 3500 HP motor—250 RPM—each spindle 78 RPM

Helical gear drives can and have been made with ratios as high as 100:1, and have been used in comparatively large installations with ratios of 30:1. The objection to the high ratios is mainly an economic one. The pitch diameter of the driving pinion must be sufficient to carry the load and accommodate the shaft. If the ratio is 30:1 the gear wheel is thirty times as large as the pinion, and for all practical purposes the center distance becomes so great that the drive is out of proportion in size and in cost. Conversely, if the ratio is 6:1 and a double reduction used, the first pair of gears will have a ratio of 3:1, and the second pair of gears a ratio of 2:1. There will be introduced two pairs of gears, six bearings and small ratios which are not desirable. Furthermore, the cost of this double reduction unit, because of the added number of parts, will be greater than that of the single reduction unit. The results of experience show that where the ratio does not exceed 12:1 a single reduction gear set is the best.

Tooth Contours

The correct form of tooth profile has been investigated by many able mathematicians and its laws clearly stated. Proof has been established that the common normal to the tooth curves at the point of contact must pass through the pitch point. There are an infinite variety of curves which will satisfy this condition, but only one—the involute—has the characteristics which make it the most suitable for practical purposes.

The important feature of the involute tooth is the wide variation in center distance which is permissible between the shafts without destroying the tooth action or departing from the law of gear tooth curves. Nearly all gears at present are so made. The cycloidal contour, which requires rigid adherence to center distance, is used in but comparatively few instances.

Pressure Angle

The pressure angle of approximately 20° has been adopted for industrial helical gears. Much time and thought has been given to the study of pressure angles, but with little convincing conclusions. High pressure angles improve the physical appearance and structural strength of the gear tooth. Low pressure angles, however, increase the number of teeth in contact and the length of the line of contact. Apprehension over the unfavorable effect of high pressure angles on the bearings has disappeared.

Helical Teeth

Experience has shown that helical teeth, which actually consist of a succession of infinitely narrow straight tooth spur gears, offset with a definite mathematical relation, have better operating characteristics and are much more suitable for the heavier and higher speed gear sets.

The helical teeth introduce many points of superiority over the straight teeth. They are far more quiet and less susceptible to vibration. They are especially suitable for higher speeds, heavier loads and abusive service. Helical teeth do not strip. The combined characteristics of overlap or interlacing of the teeth, creeping engagement and inclined line of pressure retard their wear and maintain the involute profile and correct tooth action throughout the life of the gears.

The advantages which the double helical teeth hold over the single helical teeth of the same helical angle and specifications are the elimination of axial thrust on the bearings, and the complete absence of any canting of the gear wheel, due to the application of a side pressure at the rim of a cylinder of such large diameter. There is no way to overcome these handicaps except by using herringbone teeth. For industrial installations, therefore, high helical angles are used only with herringbone gears, except where the conditions of service require axial movement; which, of course, double helical gears do not permit.

The benefits from the use of helical teeth are in direct proportion to the increase in helical angle. The main drawback is the cost for their production. The 30° helical angle, which was adopted by the British Admiralty during the war as representing the best condition for manufacture and operation, has been accepted in this country for the majority of industrial installations.

Gear Sizes

Much has been written and numerous discussions have centered about the selection of gear sizes. All of the accepted gear formulae are empirical. With few exceptions each one can be reduced to a factor for the safe load which the gears will handle, and a group of miscellaneous factors to adjust for the material to be used, the pitch line velocity, the accuracy of manufacture, type of mounting, lubrication, expected service, etc. No expression has yet been evolved which is mathematically complete or accurate.

Specification of the pitch is left out to avoid incorrect and dangerous increases in the rating of gears by introducing a coarser tooth. With the bigger pitch the individual tooth becomes larger, stronger but less accurate in contour and spacing, the number of teeth in contact becomes less, and the smoothness of operation is impaired. It is now generally believed that a finer pitch with more teeth in the gear is an improvement except where extreme loads and abusive treatment are expected.

Stripped of its decorative symbols, one well known gear formula states that gears can be expected to give unlimited service if the pressure per inch of face width per inch of pinion pitch diameter does not exceed 100#, a certain figure which experience has dictated as conservative. It is customary, except with small ratios, to assume that the pinion is weaker than the gear wheel and to make the calculations accordingly.

The mathematical expression for this load factor is as follows:

$$Q = \frac{P}{WxD} = 100\#$$

Q = Load factor in pounds
P = Tooth pressure in pounds
W = Face width in inches
D = Pitch diameter in inches

The load factor Q is adjusted for the steel used in the pinion through the material factor S.

Material Factor S

S	Pinion Specifications		Recommended for Gear Wheel	
1.0	.40 to .50 Carbon Steel—	175 to 200 Brinell	.30 to .35C. Steel Casting	
1.2	.50 to .60 Carbon Steel	200 to 225 Brinell	.30 to .35C. Steel Casting	
1.4	SAE-3240 or Equivalent	225 to 250 Brinell	.40 to .50C. Alloy Steel Casting	
1.6	SAE-3240 or Equivalent	275 to 300 Brinell	.40 to .50C. Alloy Steel Casting	
2.0	SAE-3240 or Equivalent	400 to 450 Brinell	.40 to .50C. Alloy Steel Casting	300 B.
2.5	SAE-3240 or Equivalent	500 to 550 Brinell	.40 to .50C. Alloy Steel Casting	300 B.
2.5	SAE-2320 Case Hardened	500 to 550 Brinell	.40 to .50C. Alloy Steel Casting	300 B.
3.0	Nitrided Steel	600 to 650 Brinell	Alloyed Forgings	500 B.

Further adjustment to Q is made through the factor K, which corrects for the effect of tooth velocity and the precision of manufacture and installation.

Velocity Factor K

0 to 500 f.p.m.	1.4
500 to 1,500 f.p.m.	1.2
1,500 to 3,000 f.p.m.	1.0
3,000 to 5,000 f.p.m.	.9
5,000 to 10,000 f.p.m.	.8
10,000 f.p.m. and up	.75

The factor L considers the lubricating system which will be used and the expected suitability of the lubricating compound; and also takes into consideration the size of the housing and its oil capacity, the arrangement of the gears and the location of the set with relation to other equipment.

Lubrication Factor L

Open Gears	.8
Enclosed Gears—Splash Lubricated	1.0
Enclosed Gears—Positive Circulating System	1.2

Unfavorable proportions or location of the gear set to be adjusted accordingly.

Many miscellaneous factors, such as class of service, type, rating and torque variations of the driving unit, flywheel effects, etc., are grouped under the service factor Z.

Service Factor Z

	Continuous 24 hr. day	Continuous 10 hr. day	Intermitt. over 5 hr. day	Intermitt. under 5 hr. day
Full Load with Shutdowns only for Repairs	.45	.60	.80	1.10
Friction Loads to Full Motor Overloads with Frequent Power Fluctuations	.60	.80	1.10	1.50
Friction Loads to Part Full Load Rating, Average Running ¾ Full Load Rating	.80	1.10	1.50	2.00
Friction Loads to Part of Full Load Rating, with greater Service under ½ Full Load Rating	1.10	1.50	2.00	2.70

These factors can be collected as follows in a single formula which can be used conveniently to determine the power transmitting capacity of the pair of gears.

$$HP = \frac{Q \times W \times D^2 \times N \times S \times K \times L \times Z}{126{,}000}$$

Any such formula or expression is proposed for guidance only, and to assure that the recommendations of the designing engineer will be consistent and conservative. The specification covering the gear set must be tempered by his experience, his sense of proportion and his good judgment, just as with the design of any other piece of equipment.

Probably it is the recognition of the complexity of these factors entering into the design of a successful gear drive which has discouraged the attempts to evolve a truly mathematical formula for rating gears. Such an expression would be complicated and difficult to use. Furthermore, many of the factors defy mathematical treatment; and certain ones, like operating temperature and characteristics of loading, vary during the period of operation.

PART III—DESIGN

Economy in manufacture and the influence of competition makes it important for the designing engineer to use, wherever possible, existing drawings and patterns and to standardize as much as he can. All too many customers need special features and great skill is required to include these without excessive development expense.

Housings

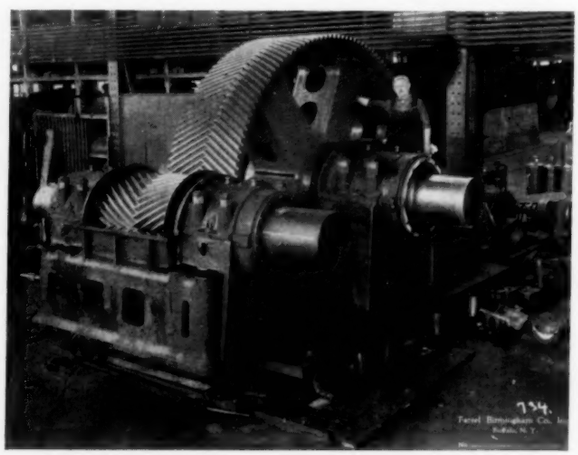
There are four materials from which the gear set housings are made: cast iron, alloy cast iron, cast steel and welded steel plate. Most of the installations use cast iron throughout. Alloy cast iron, although possessing certain advantages, is rarely specified; and cast steel has never been favored to any great extent. The past few years have seen significant progress in the adaptation of the welded steel plate construction for the complete housings or for the top covers and bottom pans, where cast iron or cast steel beds have been retained.

Cast Iron

The reason for continuing the use of cast iron in gear set housings is difficult to explain. Cast steel can be used with only slight changes of patterns and, of course, welded steel plate requires no pattern expense at all. It is probable that recognition of the rigidity of cast iron and its capacity to resist bending and weaving, coupled with the need for heavy weight to dampen vibration, have been the supporting reasons for retaining the cast iron. The success of the drive depends upon the accuracy with which the gears mesh when in service. To assure the best operating conditions the housing must absorb completely the stresses from the mating gears, and hold the shafts in rigid alignment and at the correct center distance. It is natural, therefore, that departure from the specifications, which experience has proved successful, will be slow and cautious.

Welded Steel Plate

The use of welded steel plate introduces greater freedom in design and the units, so built, can be



Typical heavy duty main mill drive, equipped with sleeve bearings—5000 HP motor—360 RPM—mill speed 60 RPM.

proportioned to suit the desired arrangement of the gears and to conform to the local requirements. It is unlikely that steel plate will supplant entirely the cast iron housing, especially in the smaller sizes which have been standardized, and for which complete pattern and jig equipment is available. It, however, will play a very important part in gearing during the next few years and will improve materially present ideas of gear case design.

Building the housing complete from welded steel plate introduces no more difficult problems than are encountered in designing other classes of equipment for this same material. The appearance of the cast iron unit can be preserved or can be altered as desired. The important factor is to make use of sections which are best suited for welded construction, and which will provide the maximum rigidity and strength for the weight involved. At the present time the cost of these housings exceeds the cost for cast iron where patterns are available, but has a decided advantage with special designs where new patterns are required.

The more complicated parts, such as bearings and

caps, are made from cast steel and welded in place to the plate frame. Because of the freedom in using different thicknesses of plate in a single piece all of the component parts can be built to function as structural members, adding thereby to the rigidity of the complete housing and eliminating unnecessary weight in the beds.

Gear Wheels

Until recently the design of gear wheels has conformed to the practice built up many years ago, and has adhered to the use of carefully annealed steel castings of the conventional H or inverted H arm construction. The rim, arms and the hub have been made from a single casting, except where the installation has required the wheel to be in halves. The proportions, number of arms, the contours and thickness of metal have varied with different designers, and in the larger gears the hub has been split for foundry reasons and shrink rings used for clamping to the main shaft. There is no question that the cast steel wheel has met the demands of service unusually well and has proved economical to produce.

Within the past few years there has been introduced for industrial gear sets the type of gear wheel which is standard for the high speed turbine units. A forged or rolled steel rim is shrunk onto a semi-steel core, which is mounted on its shaft before the teeth are cut. This is more costly and becomes heavier in weight than the cast steel gear wheel, but the strength and accuracy of the gear teeth is improved. Its use is confined to comparatively small pitches.

Of late considerable interest has been aroused in the use of welded steel plate for gear wheels. Although a number of different designs have been offered, these in general recommend a rim formed from a plate and a steel hub with connecting arms, or web, made from welded sections. Despite the criticism against certain features in this construction which depart from previous ideas, the results have been satisfactory. Naturally the weld in the rim follows the helical angle to be cut.

A very recent innovation in gear wheels uses a forged steel ring having special annular flanges, to which are bolted dished steel discs which in turn are bolted to flanges forged in the main shaft. This construction incorporates all of the advantages of the forged steel rim without the added weight and expense of the semi-steel core and, furthermore, it eliminates entirely the hub and its attendant machining operations. The bolts permit the selection of any desired chemical and physical specifications, and heat treatment for the ring—also its quick removal if necessary.

Pinions

Except in the selection of materials and heat treatments, there is little call for ingenuity in the design of the pinions. In heavy duty gear sets these are forged integral with their shafts which are provided with the necessary collars, slingers, grooves and keywayed extensions. To avoid undue bending the face width should not exceed three times the pitch diameter and the bearings should be located close to the sides of the pinion.

It is customary to increase the pinion addendum and decrease the addendum of the gear wheel teeth in the ratio of approximately 3:1, and to adjust the dedendums accordingly. The advantages gained include greater structural strength of the pinion teeth and increase in the arc of recess.

Pinions with few exceptions are made from steel forgings and are identified through specifications adopted by the Society of Automotive Engineers. It is usual to state that steels equivalent to the SAE specifications are acceptable to take advantage of the special steels which are put out under trade names.

Heat Treatment

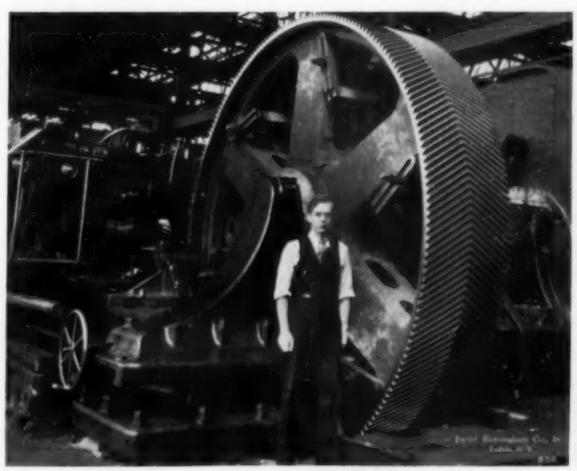
The pinion teeth in heavy duty gear sets are heat treated. Most specifications call for quenching and drawing the rough turned forging and machining it in its hardened condition. This method is convenient and relatively inexpensive, and eliminates distortion but places a top limit of approximately 300 Brinell.

For increased strength the forgings, after machining, are quenched in oil and drawn to the desired hardness, seldom in excess of 450 Brinell. For accuracy and high speeds an intermediate normalizing operation is introduced after rough machining. This relieves the residual strains and those introduced by the machining operations, and reduces materially the distortion of the gear teeth during the subsequent quenching; but it is expensive.

In the smaller sizes effective use is made of nitriding steels. These require a temperature of approximately 900° F. for the heat treating and develop hardness numbers in excess of 700 Brinell without the slightest indication of distortion. The forgings are expensive and limited in size and only a few nitriding furnaces are available. Where intricate sections are required, however, the expense and inconvenience is justified.

Carburizing, or case hardening, produces a soft core and a hard surface between 500 and 550 Brinell. It is claimed that distortion to a certain degree is inevitable and that it introduces a wide difference in chemical and phyical characteristics between the hard case and the soft core.

Recent advancement in the art of torch harden-



Typical large main roll mill drive gear wheel mounted in Sykes gear generator.

ing has produced valuable results. This is a surface hardening process, involving heating and quenching, which is carried out on a very small part of the tooth with no opportunity given for distortion. Each tooth is heated by an acetylene flame of suitable contour and intensity, which is followed by a jet of water. The relation between the temperature of the part under the flame, the interval before it is quenched, and the amount of water which is directed to it, determines the hardness of the surface and the size of the core. This method is applicable to castings as well as to forgings.

It is claimed that torch hardening is preferred to case hardening because it includes the use of a tougher core, less drastic heat treating operations and internal strains, uniform chemical analysis and a negligible amount of distortion. Experience and technique in torch hardening is of the greatest importance. Serious damage or inequalities of structure can result from slight variations in heating and quenching.

Recently there has been introduced a process of selective hardening. The entire forging is heated to between 900 and 1000° F. and the teeth in the periphery quickly raised to the desired hardening temperature, followed by a quench in oil or water. It is claimed that this produces a pinion having all of the advantages of torch hardening, and with exceptional uniformity of physical structure and characteristics.

Sleeve Bearings

Sleeve bearings in heavy duty gear sets are either ring oiling, collar oiling or pressure lubricated. With few exceptions they are lined with tin base babbit metal poured into cast steel split removable bushings which, to improve the bond, have been machined and tinned prior to pouring the babbitt metal. Where the space available for these bearing shells is small or where water cooling is required, bronze is used in place of steel.

The most important feature in the design of the sleeve bearing, and the one to which much study and research have been devoted, is the distribution of the lubricating oil from the entrance ports to the areas of pressure or contact. It is the general practice to accomplish this with grooves cut from the entrance ports to the regions ahead of these pressure areas. The action of the rotating journal, in combination with long sloping chamfers of correct shape for the lubricant used, introduces the oil between the working surfaces. It is seldom that it is fed directly to the areas of pressure.

Space will not permit detailed presentation of the many combinations of grooves and chamfers and the relation of the type of lubricant to their location. They all are reliable and effective if they distribute the oil in sufficient quantity and facilitate its pick up by the rotating shaft.

The sleeve type of bearing is preferred by certain engineers, in particular the marine group, to take advantage of the comparative ease with which the sleeve bearing can be repaired or renewed. This point carries weight, especially with installations at more or less inaccessible locations and where the facilities for disassembling the gear set are limited.

With heavy duty sleeve bearings the pressure per inch per projected area in the high speed bearings usually lies between 60 and 80#, although pressures up to 100# can be tolerated if necessary. Because of the relatively large diameter the pressures in the slow speed bearings seldom exceed 40# and frequently are as low as 10#.

Anti-Friction Bearings

Experience of the past seven years has proved conclusively that the anti-friction bearing is reliable, durable, efficient and wholly satisfactory for the heavy duty gear set. Installations have been made using anti-friction bearings as large as 23", and at high speeds as well. Until recently, however, such gear sets fitted with anti-friction bearings have been more expensive to build than the units with the sleeve type of bearings.

Because of the comparatively small pressures involved the advantages of the anti-friction bearing in the reduction unit are not as striking as on the roll neck. Compared with the well designed and lubricated sleeve bearing the increase in overall efficiency of the gear drive, based upon its full rated load, rarely exceeds ¼%. The starting torque is surprisingly small; which, however, is not an important factor.

The anti-friction bearing occupies less space on the shaft journal and requires a shorter housing, which is an advantage. It is not sensitive to lubrication. In fact, it is reasoned by some engineers that there is true metal to metal contact between the rollers and the races and that the lubricant is required merely to keep the surfaces clean and free from rust and contamination. Where anti-friction bearings are used the operating temperature of the gear unit is higher. This does not harm the drive but it does affect the lubrication.

One big difficulty with the introduction of anti-friction bearings has been to overcome apprehension over the consequences of a broken bearing. Experience gained from a large number of heavy duty gear sets has proved conclusively that any such fears are unwarranted. The possibility of breakdown is very remote and in the few isolated instances where such trouble has arisen sufficient warning has been given so that the entire installation has been shut down before damage has occurred.

Thrust Bearings

In every gear set for main mill rolls provision should be included for taking the end thrust from slight misalignments in the mill itself, and from worn wabbler parts and the like. There does not seem to be any established relation between the torque and the amount of end thrust to be absorbed by the gear set. Accordingly, provision is made at the end of the bearing shell for as much surface as can be accommodated without enlarging the housing.

Where anti-friction bearings are used the thrust is taken either through a separate thrust collar or by tapered roller bearings. If the separate collar is introduced its size is selected to fit most conveniently into the gear set housing. If tapered roller bearings are used they are selected to handle the radial loads, and their capacity for end thrust is fixed accordingly.

Shafts

The diameter of the high speed shaft in a heavy duty gear set is usually such that the torsional stress,

based upon the rated horsepower and the speed of the motor, lies between 1500 and 2000 lbs. per sq. in. The fibre stress in the slow speed shafts on the same basis lies between 2000 and 3000 lbs. per sq. in. For gear sets where the high speed shaft supports overhanging flywheels, the shaft diameter is increased to carry these overhanging weights, the amount of increase depending upon the weight and overhang—usually between 30 and 50%. To prevent undue bending the span between the bearings should not exceed six times the shaft diameter. The type of bearing, the unit pressures and rubbing speeds should be carefully considered and if advisable the shaft diameters modified accordingly.

Segregation of Lubricating Compounds

When separate lubricants are used for the gears and the bearings it is necessary to introduce details in the design which will prevent their interchange. This subject has received a large amount of study and many ingenious ideas have been worked out so that today it can be accepted with perfect confidence that these lubricating compounds can be confined to their respective chambers.

Space is not available to describe the many schemes which are employed. They vary all the way from a complete separation of the chambers with a wide gap between them through the many combinations of oil rings, slingers and baffles to the use of the packing gland. The separate bearings are lubricated by oil rings or collars and provided with individual oil level gauges. It requires just as much ingenuity to house anti-friction bearings and seal them against the infiltration of gear compound as for the sleeve type bearings.

Vents

The subject of vents, or breathers, in the covers has received much thought and is one over which there is some difference of opinion. If the vent is used it should be accompanied by an air intake to provide a positive circulation or scavenging of the air within the top cover itself. The disadvantage of the vent, however, lies in the opportunity it presents for the infiltration of dust; the recognition of which condition is substantiated by the elaborateness of its design.

Miscellaneous Details

Every gear set includes a number of detailed features, such as inspection covers, baffles, troughs, ducts, oil gauges, etc., which are standardized and need no further description. The well designed gear set not only requires careful attention to each and every engineering detail but should be attractive in appearance. Smooth surfaces, easy contours, machined and polished nuts and plugs, and a good job of painting or enameling and decorative lettering put finish to the design, the advantage of which cannot be ignored.

Flywheels

This is a timely place to point out that the last decade has seen the almost unanimous adoption of steel plate flywheels for main roll drives. These became a necessity with the use of higher motor speeds. Overhung flywheels with peripheral velocities in excess of 15,000 f.p.m. are not uncommon today. The very satisfactory experience with the plate flywheels has led to their substitution for cast steel at slower speeds, sacrificing certain effectiveness in weight distribution for perfect balance and safety together with economical manufacture. Most of these flywheels are forced under pressure on extensions to the pinion shaft, although occasionally they are bolted to special flange hubs for ease in assembly.

Flexible Couplings

Although actually a separate piece of equipment, the flexible coupling functions as an inherent part of the gear set. It has a difficult duty to perform in that it must compensate for misalignment and permit relative axial movement between the shafts. Many satisfactory and reliable installations attest the success of the flexible coupling designs. Generally speaking they are divided into two groups.

The gear tooth type depends upon the use of a floating sleeve or spindle in conjunction with two hub pieces. It relies upon the rocking motion between the interposed teeth or jaws in the hubs and the connecting sleeve or spindle to compensate for the misalignment and prevent strains on the bearings. Many different designs of this type of coupling are offered; the oldest and most common used is the familiar wabbler and spindle connection.

The second group of couplings include the use of springs or resilient materials to provide torsional resiliency. In some designs misalignment is handled through a floating member and in others it depends directly upon the movement of the resilient material.

PART IV—MANUFACTURING METHODS

The past decade has seen important developments and improvements in the methods of manufacturing gear sets. The demands for higher speeds, greater loads and smoother performance have come from every class of industry. Large sums of money have been expended in study and research and the results have been decidedly worth while.

Accuracy

Gears today, even in the very large sizes and coarse pitches, are produced with such accuracy that special, delicate instruments are required to measure them. This demands excellence, not only in generating the gear teeth, but in the turning and boring operations and usually includes for mounting the gear wheels as well as the pinions on their respective shafts before the cutting operation, so that the teeth will be generated concentric with the journals.

It is not uncommon to specify that the cumulative error in a gear wheel 36″ in diameter and approximately 12″ face shall not exceed .003″, and that the tolerance in tooth to tooth spacing shall be less than .001″. The cumulative error in a 3″ pinion to mesh with this gear should be less than .001″. Gears having a diameter of 12′ and a face width of 40″ and with a pitch as coarse as 1 DP are produced with a cumulative error of .008″, and a variation in tooth spacing of .002″.

Gear Generating Machines

Gear generating machines are available today which will produce helical or herringbone teeth as coarse as ½ DP with the same methods and proportionate accuracy as are demanded for high speed power plant and turbine work. The double cutter machines generate both halves of the double helical

teeth at one time and at the same point on the periphery. They represent years of study and development, and experience with the production of many thousands of gear sets operating in every class of service. Items, far too numerous and detailed to be discussed here, have been given continued study, such as the cutting tools, their method of manufacture and sharpening, the maintenance and adjustment of the machine, the change gears, etc., all of which have their direct influence on the accuracy of the finished teeth. The machines will generate with equal facility straight, single or double helical teeth, with helical angles in actual installations up to 56°, and pressure angles as high as 30°. The herringbone teeth usually are continuous with sharp apices and full bearing across the entire face width. They can run in either direction with equal efficiency and ease. The profiles are proportioned with large fillets to produce a strong tooth structure.

Lapping

Recognition of the advisability of running in gears before placing them in operation has developed the art of lapping and burnishing the teeth. Burnishing in large gear sets is not convenient, but lapping has long been used with excellent results. Special compounds are prepared by the larger abrasive manufacturers, which experience has shown are excellent for this work. They come with the correct consistency for ordinary usage but can be thinned out for special conditions. A most convenient and simple procedure is to pour or brush the lapping compound onto the gear teeth as they are rotating and as their direction is reversed. The teeth are subsequently cleaned by washing with water, followed by coal oil. Refinements have introduced the use of a special pinion for this lapping operation, made from cast iron, usually with a diameter larger than the driving pinion. This permits of a thorough lapping of the gear teeth in both the pinion and wheel without danger of removing too much metal and with the assurance of the smooth, even bearing surface which is the objective sought for in lapping operations.

Testing

It is difficult to test the large size gear set under load in the shop of the builder. In accordance with general practice these gear sets are run under partial load before they are shipped for installation, and are started up with service load under the supervision of the gear builder.

PART V—LUBRICATION

All steel mill engineers and executives recognize the importance of lubrication and the detailed specification of the system and oils which will be used. Each loaded part in the gear set, with the possible exception of the anti-friction bearings, is carried on a film of oil and seldom fails unless there has been an actual puncture of this lubricating film. With the development of new lubricating oils and of the Extreme Pressure Compounds it is possible to increase the permissible loads on the gear teeth and journals, and to introduce additional benefits by way of durability, freedom from mechanical shut-down and savings in operating cost.

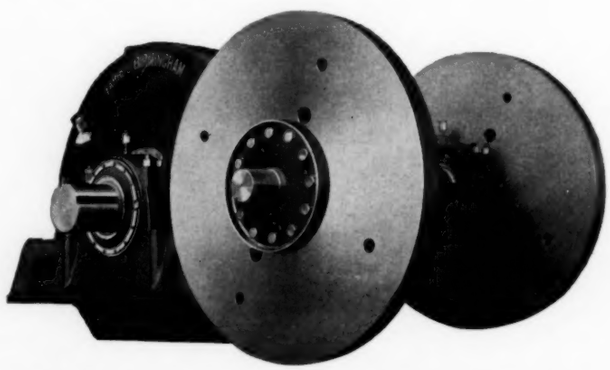
There are two accepted systems for lubricating main roll gear sets, the splash and the pressure or positive circulating types.

Splash System

The splash system depends upon the action of the teeth in the gear wheel as they pass through a reservoir of lubricating oil in the base of the housing. As the name signifies, the lubricant is splashed in a finely divided state which permeates everywhere within the housing.

To avoid churning and foaming and undue friction loss, the teeth in the gear wheel should dip only a comparatively small amount into the reservoir of lubricating compound. Just how deep depends on the tooth velocity, the pitch, the design of the wheel and the type of lubricant—usually a little more than their own depth.

Experience shows that it is necessary that there be a large amount of lubricating compound in the reservoir. This requires a big trough which should be of almost rectangular section and at no point close to the rotating gear teeth, and maintained with an ample oil supply at all times.



Typical large double reduction gear set fitted with plate flywheels and anti-friction bearings. 1600 HP motor at 360 RPM—mill speed 30 RPM. Flywheel capacity 30,000 HP seconds.

Where the splash from the gear teeth is to lubricate the bearings it is usual to collect the lubricant which is thrown onto the inside of the cover in troughs cast as a part of the housing, from which it is led to the bearings through passages or ducts. Return to the reservoir is through draining canals. Suitable seals are provided to prevent leakage from the bearings to the outside along the extended shafts. Sometimes special baffle plates or drip fins are used to further direct the lubricating stream.

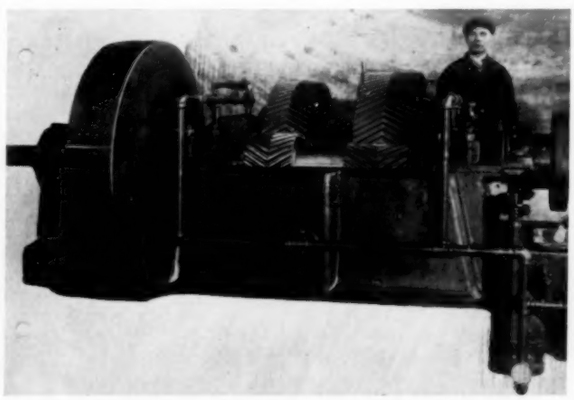
Positive Circulating System

The positive circulating or pressure system supplies the lubricant under pump or gravity pressure through feed pipes, directly to the line of tooth engagement and to the individual bearings. It is used where the peripheral velocities and bearing speeds become so high that the oil churns and heats excessively if the teeth are allowed to dip into it. Also, at the very high speeds the lubricating oil is thrown off of the gear teeth by centrifugal force and must be applied directly to the line of tooth engagement through specially designed spray nozzles. Positive circulation is used in slower speed gear sets because it improves the overall efficiency of the unit and eliminates the "human element"; also in special designs which cannot be lubricated conveniently by splash.

Real ingenuity has been displayed in the layout of these positive circulating systems, and in the equipment which they require. A pump is included, usually of the gear or rotary type, driven directly from the gear unit itself through gears or chains or by a separate motor. Either way is reliable and requires little power. It is customary as a safeguard to include tell-tales or relays in the electrical hook-up to insure a warning or to shut down the rolling mill if the pressure in the feed pipes becomes too low.

Individual pipes are used instead of passages in the castings which frequently are dirty and contaminated with core sand and often are actually leaky. Seamless steel or copper tubing is used although recently malleable iron has been introduced. Bends are better than elbow fittings, and the use of individual pipes instead of header distribution.

Large drain pipes are essential. The flow of the lubricating stream is restricted by backing up in the small drain pipe, fully as much as by an obstruction in the feed pipe.



Two-speed unit driving 10" bar mill—500 HP motor—860 RPM. Selective mill speeds—165 and 275 RPM—flywheel capacity 5000 HP seconds.

Convenience in installation coupled with the necessity for operating instruments has introduced many standardized fittings, such as spray boxes and nozzles, pressure gauges, flow indicators, relief and control valves, electric relays and warnings, and the like.

Impurities and Moisture

Impurities and moisture have injurious effects on the performance and life of gear teeth and bearings, which are accentuated by high lineal velocities. In the majority of installations such contamination is removed by a complete change of the lubricating compound, accompanied by a washing of the gears, bearings and housing. The intervals between these changes vary widely and are determined by the character of the service. Usually they are far too infrequent. Discharge of impurities and moisture from the circulating stream is assisted by designing the contour of the housing and sump tanks to provide resting or settling spaces. With the pressure systems it is customary to include special equipment for filtering the lubricant and actually separating it from the acquired water.

Cooling

Keeping the lubricant cool involves two factors. The first is to prevent an abnormal generating of frictional heat. The second is to provide for the dissipation of the unavoidable heat.

The ordinary frictional heat is dissipated by radiation from the housing in the great majority of installations. Large reservoirs of lubricant, spacious covers and circulation of air around the bases and bottom pans lower the operating temperature. Where box sections are used openings should be inserted in the outer and cross walls to assure effective ventilation.

Where the size of the gear drive is small compared with the power transmitted separate coolers or cooling coils are needed. These are included with splash as well as positive circulating systems; and with certain installations are used to heat the lubricant in the winter months.

The cooling coils usually are made of copper and are installed in a sump tank or in the bottom of the gear drive itself. Recently the use of a cooler made from special automobile radiator cores has been tried out with success. The advantage lies in its compactness and cheapness, also in its effective heat transfer. It is available with the pump, filter and accessories, in one self-contained unit which is simple and convenient to install.

Centralized Circulating Systems

Whether the equipment for circulating the lubricating compound is incorporated as an integral part of the gear set or whether it is furnished as a separate unit by engineering companies specializing in this class of material, is a matter of preference by the purchaser. Also, whether a central system is provided which will lubricate a number of gear units including the pinion stands or whether each gear set will have its own circulating system, depends largely on local conditions.

The single central system is best used with a series of gear drives not too widely spaced and requiring the same type of lubrication and operating under the same class of service. It is less expensive to purchase and install but it is not as flexible to handle and has the very serious danger of contamination and waste. Obviously the greater the number of outlets and return drains, the more surfaces are exposed to accumulate foreign matter and water, and the greater the likelihood that the system will pick up these impurities and carry them throughout its entire length and into the large reservoir of lubricating oil. Furthermore, any damage to this central system results in a complete shut-down with the possible ruin of its entire supply of lubricant.

Specification of Lubricating Compound

Despite universal recognition of the importance of specifications covering the lubricating compounds, it is difficult for the designing engineer to do more than recommend the approximate viscosity zone and quality of oil to be used with his equipment. It is expected that the work of several technical associations and trade organizations towards standardization of these lubricating oil specifications will simplify this problem and make possible a concise definition of the properties required without violating neutrality toward the individual oil producers. This will enable the designer to take advantage of the wide difference in lubricants and their effect on wear, mechan-

ical efficiency, noise, vibration and work life of the gear set; and, of special importance, to assign different ratings for the same size of gear drive, depending upon the specific lubricant to be used.

Source of Crude

The type of crude oil from which the lubricating compound is made is the most important factor. There are sharply defined properties which are characteristic of the Pennsylvania, Mid-Continent, Gulf and Pacific Coast crudes which identify their relative values as lubricating compounds. Oils made from these different crudes can have identical viscosities at 100° F. and surprisingly different lubricating values.

Oil Body

Next in importance to the source of crude is the body of the oil. On this property depends the load carrying capacity or resistance to rupture of the lubricating film, and it is interest in the improvement of this property that has prompted the development of the Extreme Pressure lubricants. The natural body of the oil depends entirely upon the source of the crude. It is possible, however, to artificially strengthen this by combining the oil with certain inert substances or through a chemical process of sulphurizing. Whereas such developments require time to substantiate their value, there is every indication that either of these methods produces a decided improvement in the body and load carrying characteristics of the lubricant, and without introducing any harmful effects.

Viscosity

Custom has developed the use of viscosity to describe the characteristics of lubricating compounds. This has led to confusion and costly misunderstandings. The viscosity has been specified at one temperature only, usually at 100° F., which, without further elaboration, has introduced a wide difference, both in quality and characteristics.

The intelligent use of viscosity requires its exact specification at no less than two temperatures; namely, 100° F. and 212° F., and preferably at the expected operating temperature. A first-grade Pennsylvania oil with a Saybolt viscosity of 1560° at 100° F. will have a viscosity of only 400° at 145° F., and 120° at 212° F. The properties of this oil and its usefulness as a lubricant will be governed accordingly.

Comparatively high operating temperatures do not harm the gear set itself but they are serious in their effect on the characteristics of the lubricating compound. Gears are not delicate, nor are they especially sensitive to lubrication. There is no question, however, that their operating performance can be improved materially and their load carrying capacity increased by maintaining the temperature as low as possible and preserving thereby to the fullest extent the value of the lubricant.

Effect of the Lubricating Stream on Efficiency

There is little information as to the effect of the lubricating stream on the efficiency of a gear set and on its operating temperature. We know that undue churning of the oil produces internal friction accompanied by heating and power loss, and that the application of load introduces little increase in friction. The amount of agitation within the lubricating stream appears to be the important factor. With the splash system too much dipping of the gear wheel teeth, too high velocity and the use of fine pitches contribute to frictional loss and heat. With the circulating system the length and intricacy of the distributing pipes, the design of the pump and strainer, and the size of the oil stream are very important. Without question a special study of this subject should be productive of interesting and valuable results.

PART VI—INSTALLATION AND OPERATION

The heavy duty reduction gear set is a very important piece of machinery, usually running at comparatively high speeds and under heavy conditions of load. It is not enough that it shall be designed and manufactured with exceptional care and accuracy; it also is essential that it shall be carefully installed and operated.

Erection

Erection of a gear set is not difficult but should be entrusted to the care of experienced men; and special attention should be given to the following points, especially where for transportation and handling purposes the unit has been shipped partially disassembled.

Gears and all contacting surfaces should be examined to discover any damage which may have occurred in transit. Bruises or burrs should be removed and the surfaces carefully washed clean from slushing compound and foreign matter.

Alignment

The housing should be level and properly supported to avoid strains and bending when the foundation bolts are tightened up. The gears should be in alignment, that is to say, the axes of the shafts should be perfectly parallel. It can be assumed that if the teeth show a perfect bearing surface along the whole of the face width the alignment of the axes is correct. To make sure of this it is advisable to coat the pinion teeth with a fairly thick layer of Prussian blue or red lead, then turn the gears around by hand or run them at a very slow speed by power and observe whether the marking is uniform over the whole length of tooth. If it is not even a little careful consideration will make it obvious which way to adjust the shafts to get the proper alignment.

The bearing surface over the tooth contour also should be reasonably good, but the erector can do nothing to alter this beyond getting the parallelism already referred to. It is advisable to point out, however, that a bearing on the pitch line is not essential in involute gears; moreover, this pitch line may not be midway between the root and the top of the teeth, as it is often thought. The mechanic therefore should forget all about pitch lines when dealing with involute gears. A good bearing surface is necessary but it should be fairly uniform all over the teeth and not necessarily concentrated where the pitch line is thought to be.

Backlash

Gears should not be crowded into mesh where there will be an artificial tooth load created which may result in too high surface pressures. A considerable amount of blacklash is advisable, the maxi-

mum amount permissible depending considerably on the pitch of the teeth. A backlash of .035" is not too much for 1 DP. In smaller pitch gears the maximum backlash should be in direct proportion, that is to say, about .01" per inch of circular pitch.

Axial Adjustment

In herringbone gears the sideways adjustment is important unless either wheel or pinion is free to float. It is common practice to lock both wheel and pinion endwise or to limit the axial movement of one or the other to a very small amount. In such a case care should be taken to prevent one helix taking all of the load. The marking of the teeth by coating the pinion, as above explained, will indicate whether or not the endwise adjustment is correct. After the gears have been in service for a short time inspection will show whether the load is carried uniformly on both helices of the driving sides; and, if not, the wheel or pinion should be further adjusted to obtain the desired results.

Inspection

Periodic inspection of the gear teeth and bearings, and of the condition of the lubricating oil is necessary for the successful operation of gear drives. The frequency and method of inspection depends upon whether the unit is lubricated by splash or by the pressure circulating system, and upon the organization of the mill personnel. Too frequent inspections are much better than too few. Gear teeth and shaft journals give ample warning of incorrect running conditions and of impending trouble. These warnings, however, must be heeded and corrective measures taken in time to prevent breakdown and loss of production.

Warnings of Trouble—Noise

A few remarks regarding the signs of trouble or incorrect operating conditions are desirable. The well built gear set should not be noisy but it is a mistake to expect such a unit to be absolutely silent. Occasionally this condition exists but usually there is a sound, due to an accumulation of slight inaccuracies which cannot be avoided. If this noise is audible when standing beside the housing and especially if it can be heard at a distance, its cause demands investigation. The tone depends upon the speed of the gear teeth and their pitch; the higher the speed and the smaller the teeth, the higher the tonal note. If the noise is periodic the location of the trouble is comparatively easy. Occasionally its cause is very difficult to discover.

Vibration

Vibration usually accompanies objectionable noise, although it is not as noticeable because of the damping effect of the heavy housing and the firm grip of the foundation bolts. Excessive vibration is nearly always due to either small shafts or bearings too far apart, light structure of the bearing supports or loose fitting journals, gear misalignment or incorrect mounting of the couplings.

Heating

Abnormal heating indicates the need for attention. Frequently this heating is caused by some slight local binding condition which with continued operaton will relieve itself. It is not unusual, although undesirable, for the temperature of a gear unit to lie between 130 and 140°—temperatures which are far too hot to permit holding a hand on the gear case and which, unless thermometer readings are obtained, can grossly mislead the operating engineer. Prolonged heating is usually accompanied by other indications of trouble and should be given attention and every effort made to maintain the lowest possible operating temperature.

Tooth Marking

The most important symptom of trouble is the marking of the gear teeth or the journals. Sometimes after the gears have been in use a short time rough scratches will appear on the teeth. These are due to slight burrs or grit which have not been removed in erecting the gear set. Unless they are deep it is inadvisable to touch them because, if the gears are properly lubricated, these surface scratches or score marks will soon disappear.

If after the gears have been in operation for some time the teeth show signs of pitting, spalling or tearing, this condition demands investigation. Usually the spalling or pitting is at the pitch line where the contact between the meshing gear teeth is purely rolling, and the tearing is at the extremities of the tooth profile where sliding contact predominates. It is generally assumed that the pitting or spalling is caused by excessive local pressure and metal fatigue, and that the tearing is caused with the introduction of sliding contact by a tearing of the tooth surfaces which have been "cold welded" together under the high pressure. Either condition is the result of a break-down of the lubricating film, through the use of insufficient or incorrect bodied oil, overloading of the gear teeth or from misalignment, inaccuracies or distortion which confine the tooth pressures to small local areas.

Corrective Remedies

Before the remedy can be applied the cause must be ascertained. Misalignment or inaccuracies should be corrected. Oil change to a compound which will withstand the tooth pressure without rupture may be required, although the results frequently can be better obtained through the introduction of cooling and circulating equipment which will reduce the operating temperature of the gear set and improve the load carrying characteristics of the lubricating oil accordingly. Usually by correcting the trouble the marks from spalling and tearing disappear. When these are too pronounced, however, hand dressing or recutting of the teeth is necessitated.

The Healthy Gear Set

A gear set in good condition is like a healthy individual. The smoothness and quietness with which it handles the loads, its cool operating temperature and the clarity and body of the lubricating oil show even to the casual observer that conditions are nearly perfect. Removal of the inspection covers discloses tooth surfaces and journals smooth and polished as glass.

Practical Design and Application of Resistors for D. C. Motors*

By DON. L. ORTON,
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Methods were given in Article I for designing a resistor to effect a 50% total speed reduction on a constant horsepower drive. Should intermediate speed points be desired between the base and reduced speed values the problem is only slightly complicated. It is necessary, of course, to make a separate calculation for each required speed point. The total resistance required for the lowest speed desired is readily computed and the correct points at which taps are to be taken from the resistor for intermediate speed points obtained from individual calculations. However, a tabulation is advisable in order that a common sense check can be easily made. To go a step farther with the above example let us assume that the base full field full load speed of the shunt motor is 1150 RPM and that it is desired to reduce this speed 50% to 575 RPM with five intermediate speed points, the series armature resistor to be designed to give equal increments of speed change. Using the formula and other values as given in the last part of Article I, the tabulation would be as illustrated by Fig. 6.

Speed	Line Volts	Armature Volts	Resistor Volts	Armature Amperes	Required Ohms In Resistor
1150	230	230	0	40	0
1055	230	211	19	40	.475
960	230	192	38	40	.950
865	230	173	57	40	1.425
770	230	154	76	40	1.900
675	230	135	95	40	2.375
575	230	115	115	40	2.880

Resistor Tabulation for Speed Control of Constant Torque Drive.

FIG. 6

From the tabulation taps can be properly taken from the resistor for the intermediate speed points but it is to be noted that no tapering of capacity is possible since the same amount of current is taken at all speeds.

The foregoing discussion has considered, in the interest of simplicity, only shunt wound motors as applied to constant torque drives. Very often the characteristics of compound wound motors are better adapted to applications of this kind. However, the calculations given in the foregoing for shunt motors apply equally as well to compound motors on constant torque drives. Since the current through the armature and series field of a compound motor remains constant through the speed range on a constant torque drive, the speed of which is reduced by series resistant, the amount of compounding effect will likewise remain constant. If the compound field effects a reduction in speed of 30 RPM at the high speed it will likewise produce the same reduction in RPM at the low speed. Therefore, if current and speed measurements are made with the motor directly across the line and operating at its full field speed a required speed reduction can be obtained by means of series resistance by following the procedure outlined above for shunt wound motors. These facts also hold true for series wound motors operating constant torque drives since the field strength depends entirely upon armature current which we have proven remains constant through a desired speed range.

Constant horsepower drives present an entirely different aspect to our general problem of speed control by means of series armature resistance. The metal lathe referred to in the foregoing is an excellent example. At the higher speeds a less cut is made in turning metal resulting in reduced torque required with increasing speed. Bearing in mind the fundamental relationship that horsepower is always proportional to the product of torque and speed it is obvious that the metal lathe falls in this general class of application. Assuming a shunt wound motor we again express the relation between torque, field strength and armature current—

$$T = k\Phi I$$

Transposing $$I = \frac{T}{k\Phi}$$

Where:

T = Torque
K = A constant
Φ = field strength depending upon motor design
I = armature current

Since we are dealing with a shunt motor of constant field strength the denominator of the fraction may be considered as a constant with the armature current varying directly with the torque requirements of the load. At the higher speeds less torque is required and hence less current the latter diminishing directly with increasing speed.

Let us take for example a metal lathe to which is to be applied a shunt wound motor the load current of which is found by measurement to be 40 amperes at the base full field speed, with a line voltage of 230, while driving the lathe. It is desired to reduce this base speed 50% in order to handle some very large work with heavy cuts being made at the lower speed. From the equation given in the foregoing paragraph it is clear that proportionately higher currents will be taken while making the heavier cuts at reduced speed. For the purpose of practical resistor calculations it is safe to assume an inverse ratio between speed and current and therefore at ½ speed we will have double current or 80 amperes. It is very important to check carefully the current taken by a motor on an application of this kind so as to avoid exceeding the full load current rating at any speed point. For a speed reduction of 50% the armature voltage must be reduced pro-

* The second and concluding article of a series by the author.

portionately to 115 volts. It is therefore possible to apply the equation.

$$R = \frac{E-e}{I}$$

Where:

R = ohmic resistance of series resistor
E = line voltage
e = armature voltage for desired speed reduction
I = load current of motor at desired speed reduction.

It should be noted however, that the current in this case at 50% speed will be 80 amperes. This results in an ohmic value for the series resistor of just ½ that required for a similar set of conditions applying to a constant torque drive, in order to produce a drop of 115 volts in the series armature resistance.

For intermediate speed points a tabulation should be made similar to that given in figure 6. It should be carefully noted, however, that the armature current does not remain constant as in the previous example, it being necessary to take into consideration at each speed point calculation the fact that the current increases in a direct ratio with diminishing speed. Referring to the tabulation previously given the current taken at — say 960 RPM would be computed as follows:

$$I = \frac{1150}{960} \times 40 = 48 \text{ amperes (at 960 RPM)}$$

The voltage drop required in the series resistance for this speed remains the same as previously calculated, viz., 38 volts, but a new ohmic value is necessary due to the increased current at that speed incidental to the characteristics of the load we are now considering. The new ohmic value is obtained—

$$R = \frac{38}{48} = .792 \text{ ohms to produce a speed of 960 RPM}$$

similar calculations can be made for each desired intermediate speed point.

A little consideration of the current conditions between the high and low speed points will show that no tapering of the current carrying capacity is possible. At the lowest speed value the entire resistor is in series with the armature and, since the current is greatest, viz., 80 amperes at that time, it is obvious that the total resistor must have a current rating of 80 amperes. Even though the current is considerably less at the intermediate speed points all sections of the resistor must carry the maximum current of 80 amperes when the motor is operating at the lowest speed.

The foregoing discussion with regard to constant horsepower drives has considered only shunt wound motors. In the case of compound wound motors our speed conditions are affected somewhat by the variation in current passing through the series field at the different speed points. If we assume in the above example in the above example that the shunt motor is equipped with a series field consisting of 40 turns, the compound effect at the high speed will be 1600 ampere turns, and at the low speed will be 3200 ampere turns. If design data of the motor is available it is possible to determine the actual percentage of total field strength produced by the series field coil. If not simple tests can be made on a given compound motor at five or six different loads measuring in each case the speed both with and without series field. From the values thus obtained it is possible to plot two curves, a typical pair being illustrated by Fig. 7. A test of this kind is, of course, made with full voltage across the armature.

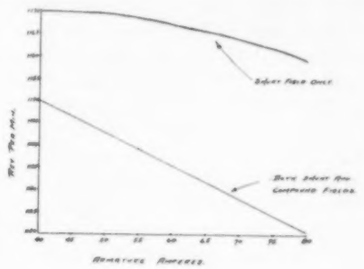


FIG. 7

A tabulation should be made incorporating the new data obtained by tests outlined in the preceding paragraph. Assuming a compound motor taking 40 amperes at 1150 RPM on constant horsepower load at 230 volts we desire to reduce this speed to 575 RPM by means of series armature resistance with five intermediate speed points as follows:—1055, 960, 865, 770, 675 and 575. This tabulation might be made as illustrated by Fig. 8. In preparing the tabulation the column of desired speeds is first filled in since these are known and required values. The values of armature current are next calculated for each speed point by dividing the base speed of 1150 by the desired speed and multiplying the result by the base current of 40 amperes. Thus, for 960 RPM we would calculate as follows: 1150÷960 x 40 = 48 amperes. However, in determining the required armature voltage for any desired speed it is necessary to take into account the compounding effect. The column headed Compounding Effect has values included that are obtained from the curves given in Fig. 7. These curves apply to a particular compound motor and a similar pair should be drawn from either test or design data, for a motor having different characteristics.

Desired Speed	Compounding Effect in RPM	Armature Volts	Resistor Volts	Armature Amperes	Required Ohms in Resistor
1150	20	230	0	40	0
1055	23	215	15	43.6	.344
960	26	197.5	32.5	48	.677
865	29	179	51	53.1	.960
770	32	160	70	59.7	1.171
675	35	142	88	68	1.295
575	38	122.8	107.2	80	1.340

Resistor Tabulation for Speed Control of Constant Horsepower Drive. Line Voltage = 230 VOLTS.

FIG. 8

The compounding effect in RPM for any given speed is defined as the difference in the ordinates of the two curves—Fig. 7—at the load in amperes calculated for the given speed. Thus, referring to Fig. 8 at 48 amperes (the calculated load for 960 RPM) the motor speed with shunt field only will be approximately 1170 RPM and with both shunt and series compound field will be approximately 1144 RPM. The compounding effect is defined as the dif-

ference and at 960 RPM will, therefore, be 26 RPM. This column can be readily completed and represents the actual reduction in RPM due to the series field that can be expected at any given calculated load in armature amperes. This effect must be taken into consideration in computing the required armature voltage for any desired speed point. At 960 RPM for instance, we can expect 26 RPM of the total reduction to be obtained by the series compound field. Therefore, in our calculation of the required armature voltage, it is necessary only to consider that we are reducing the speed to 986 RPM as the balance of the reduction is automatically obtained by the series field. The formula in this case is:

$$\text{Armature Volts} = \frac{\text{Desired speed} + \text{Compounding effect}}{1150} \times 230$$

The resistor voltage is simply the arithmetical difference between line and armature voltage and if a calculation is attempted at the base speed of 1150 RPM we arrive at a negative value for the resistors which can be disregarded. If at a given constant horsepower load the motor has a speed of 1150 RPM and draws a current of 40 amperes with the armature across the line voltage, this base speed would increase to approximately 1170 RPM if the series field is removed. This is due to the fact that our curves indicate a compounding effect of 20 RPM at the base speed. The required ohms in the resistor is calculated for each individual speed point by dividing the resistor volts by the armature amperes of that speed. Series wound motors have an inherent constant horsepower characteristic, increasing torque demand resulting in a greatly decreasing speed without the use of external resistors, and are so rarely used on applications of this kind they will not be considered here.

The third general classification of load is variable torque, the term being arbitrarily selected to indicate that neither horsepower or torque remain constant with variation of speed. A change in speed on this type of load results in a consequent change in both the torque requirements of the load and the horsepower taken by the motor. As previously stated the centrifugal fan is an excellent example of this class of drive. Centrifugal pumps also fall in this general classification but due to design and system variations, fan duty resistors are not always applicable. We have previously shown that if the speed of a motor driving a large centrifugal fan is doubled the torque required by the load will increase four times and the horsepower load taken by the motor will increase eight times. Some variations from this general ratio exist due to the difference in design of fans, but as a general rule it can be considered true for the purpose of applying electrical equipment.

Again assuming a shunt wound motor with constant field strength, we can apply the formula:

$$T = k\Phi I$$

$$\text{And transposing } I = \frac{T}{k\Phi}$$

Bearing in mind that it is a given characteristic of the load that speed variation results in a change in torque demand which is in direct ratio of the square of the speed change, we can, from the above formula say that what holds true for torque likewise holds true for armature current with constant field strength. Multiplying our speed by two results in four times the current being drawn by the armature. The formula for armature current with constant field becomes:

$$I_1 = I_2 \times \frac{(RPM_1)^2}{(RPM_2)^2}$$

Where:

I_1 = armature current at desired speed
I_2 = armature current at base speed
RPM_1 = desired speed
RPM_2 = base speed

From the equation a column of values can be calculated representing armature amperes required for any desired speed point and a table prepared similar to Fig. 8.

Assuming a motor applied to a centrifugal fan and the desire to reduce the speed in certain given increments by means of armature resistance, the required armature voltage may be calculated for any speed point in a manner similar to that given in the example for constant horsepower drives. The armature amperes for each speed point is first calculated from equation given above using these values to determine the compounding effect as previously explained if the motor be compound wound. If the motor is shunt wound the armature voltage is in direct ratio to the reduced speed and if compound wound the compounding effect must be taken into consideration as previously explained. Let us take for example a set of conditions similar to those given in the table of Fig. 8 and calculate for a certain speed—say 960 RPM—the ohmic value required at this speed for a series armature fan duty resistor. For the same compounding effect (26 RPM) the armature and resistor voltages will be respectively 197.5 and 32.5 volts. The armature current is computed from equation:

$$I_1 = 40 \times \frac{(960)^2}{(1150)^2}$$
$$= 40 \times .835^2$$
$$= 27.88 \text{ amperes at 960 RPM.}$$

The resistor voltage being 32.5 volts at this speed the necessary ohmic value is found:

$$R = \frac{32.5}{27.88} = 1.165 \text{ ohms at 960 RPM}$$

It will be noted in preparing the tabulation that in the case of variable torque drives the compounding effect is diminished with decreasing speed because of the greatly reduced currents at the lower speed points. Consideration of this compounding effect reduces to some extent the ratio previously expressed that on the larger horsepower sizes input to the motor varies directly with the cube of the speed.

A fan duty resistor designed by the foregoing method may be tapered in ampere carrying capacity due to the ratio that exists between armature current and speed. We have found that at ½ speed only ¼ current is required and, therefore, the capacity can be proportionately reduced. A tabulation should, of course, be made and an inspection of the values included in the column headed armature amperes will clearly indicate the required resistor capacity for each step or speed point.

A series armature speed adjusting resistor designed by the foregoing methods for any of the three fundamental types of load may or may not be satisfactory for use in accelerating the motor from rest. If the resistor is to serve for both acceleration and speed adjustment a check should be made to determine the current conditions with the armature at rest. Referring to the tabulation made for a typical constant torque drive—Fig. 6—a total resistance of 2.88 ohms is required to give the desired speed reduction. With the armature idle this will result in an inrush current of—

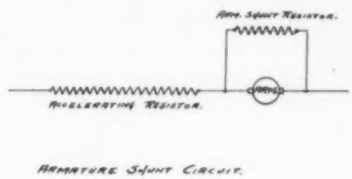
$$I = \frac{230}{2.88} = 80 \text{ amperes}$$

This is just double the full load current assumed for 1150 RPM and quite probably too great for satisfactory starting, necessitating the addition of another step used only for accelerating the motor from rest. Consideration of this question with regard to fan duty resistors will show that an exactly opposite condition generally exists. Here it will be found that the total ohmic value is usually so great that sufficient current may not be passed to break the motor and load free from rest. In this case it would be necessary to go the second or third point of the resistor in starting and then drop back to the desired speed point once the motor has accelerated. Whether or not a speed adjusting resistor is satisfactory for acceleration will depend upon the desired speed range and type of load but should always be considered in the design. An additional check should be made as to the current conditions on each point when a speed regulating resistor is used to accelerate its motor.

On certain drives a definite slow down is required during the operating cycle. For example on some types of skip hoist it is necessary to reduce the speed of the motor when the bucket approaches the upper and low limits of travel. On some very special applications having definite duty cycles, an equally definite speed is required during slow down period. Certain drives require that fairly constant speed be maintained during slow down period with slightly fluctuating loads and this condition can very conveniently be obtained with the armature shunt circuit. Rarely can the accelerating resistor of the motor be used to obtain the desired slow down characteristics and an armature shunt circuit is very frequently used on the type of drive just referred to. The standard armature shunt scheme of connections is illustrated by Fig. 9. Knowing the load conditions during the slow down portion of the operating cycle, it is possible to calculate the correct ohmic value of an armature shunt resistor to produce a desired slow down speed. It is necessary to figure the required armature voltage to give the desired slow down and to determine the load conditions at that time. Let us take for example a small coal or ash skip hoist operated by a motor that has a full load hoisting current of 40 amperes at 230 volts. It is desired to reduce the full load hoisting speed of 1150 RPM to 575 RPM for landing purposes. At the upper limit of travel the inclined rails of the skip curve over to a horizontal position for the purpose of dumping the bucket and it is during this portion of the hoisting cycle that we desire the slow down. It is known that the load current will be reduced to 15 amperes during the slow down and the field strength is assumed to be constant.

For this reduction in speed of 50% it is obvious that an armature voltage of 115 volts is necessary.

FIG. 9



The accelerating resistor which is also in the circuit during slow down has been designed to allow an inrush current of 150% (60 amperes) and will, therefore, have a resistance value of 3.84 ohms. In order to obtain the desired slow down speed we must reduce the voltage across the armature to 115 volts which means a drop in a series accelerating resistor of 115 volts. The current necessary to produce this drop will be 115 ÷ 3.84 = 30 amperes. However, our armature load current is only 15 amperes and we must, therefore, arrange to allow the balance, or 15 amperes, to flow through the armature shunt. The voltage across the armature shunt will equal the voltage across the armature which is 115 volts. Therefore, knowing the voltage across the armature shunt and the current which must flow through it, we can readily calculate the ohmic value to be:

$$R = \frac{115}{15} = 7.66 \text{ ohms required.}$$

The actual speed reduction is obtained by the voltage drop in the series accelerating resistor but due to the fact that the load current is reduced the drop would not be sufficient without the additional current taken by the armature shunt. The example assumed constant field strength but if a compound wound motor is used the effect of the series field can be determined as previously explained and the armature shunt resistor adjusted accordingly. Series motor armature shunts do not greatly complicate the problem but it is necessary to consider the effect of the field at the load during slow down. For the purpose of practical design it is permissible to consider the magnetization curve of a motor to be a straight line. If, in our foregoing example, we had considered a series wound motor, the field strength during slow down would only be approximately 75% of normal. Normal full load hoisting field strength is obtained with the full load hoisting current of 40 amperes, but since the total current passing through the series field during slow down is only 30 amperes the field strength at that time is approximately ¾ normal. This results in an increase in speed because of weakened field to the extent of about 25% above that which would obtain if the normal field remained constant. In our previous example this would result in a slow down speed of approximately 720 RPM instead of 575 RPM. In order to compensate for the increased speed due to weakened field, it is necessary to still further reduce the armature voltage in the ratio of 575 to 720 as follows:

$$\frac{575}{720} \times 115 = 92 \text{ volts (new required value)}$$

This means a drop of 138 volts is now required in

the accelerating resistor and the ohmic value remaining as before we must have total current of $138 \div 3.84 = 36$ amperes through the series resistor to give an armature voltage of 92 volts. Again inspecting the field condition we find that we will operate at reduced speed with a field strength only about 10% below its normal value. Since this is about as close as we can expect to come in practical calculations, we would base our armature shunt design on an armature voltage of 92 volts with a total current flowing through the series resistor of 36 amperes to produce the required drop. With 15 amperes of load current passing through the armature, 21 amperes must be carried by the armature shunt at 92 volts to give an ohmic value of $92 \div 21 = 4.38$ ohms. The capacity depends entirely upon the intermittency of operation and methods outlined in the article under Accelerating Resistors may be used.

Numerous other applications of resistors to direct current motors for the purpose of controlling their characteristics will frequenaly arise and the author makes no claim to having covered the entire field of application. However, with a firm grasp of the foregoing methods and underlying principles the operating engineer should be equipped to tackle and carry through to a successful conclusion any problem dealing with the application of resistors to direct current motors. Certain fundamental relationships have been pointed out which should be reviewed from time to time as they are of utmost importance for a clear understanding of the subject.

Inspection of Hoisting Chains

By A. C. BADGER,
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Presented before "Hoisting Chains" Session, Twenty-second Annual Safety Congress, Chicago, October 3, 1933.

Other speakers on this program will describe to you the causes of chain failure and the repairing, annealing and normalizing of chain. My subject deals with the inspection of iron or steel chain which is required if failures are to be avoided and if repairs and heat treatment are to be made as often as necessary.

In our mills we use chain slings to handle both hot and cold steel. The steel is in a variety of shapes, such as slabs, blooms, billets, packs of sheets, coils of wire, bundles of pipe, etc. A regular chain inspection system was inaugurated about eighteen years ago. During these years we have had very few accidents due to chain failures, none of which resulted in loss of life.

Chain manufacturers have an excellent system of inspection, which involves testing of their bar stock as received, tensile testing every few thousand feet of chain and finally proof testing and visual inspection of the finished chain. A user may be assured that chain purchased from any reliable manufacturer has been carefully inspected to insure that the chain is of good quality and up to specification in every respect. However, it must be realized that a perfectly good chain may be abused in service, or become worn, to the point that it is unsafe. Our inspection is designed to detect unsafe chain.

Chain users should purchase to specifications which will adequately define the quality of chain desired. The use of Standard Specifications for Iron and Steel Chain, A.S.T.M. A-56, is recommended.

In our mills we have a crew of chain inspectors, each man being responsible for the inspection of slings and attachments used in certain departments. These men are chosen for their familiarity with plant operations and are carefully instructed in our inspection system. They have authority to decide when any chain shall be removed from service for repair, heat treatment or replacement. In order that inspection may be uniform in all departments and inspection responsibility not divided, we have found it best to have the inspectors report to the Metallurgical Department. This, of course, does not relieve a department foreman from the responsibility of having his men use the chains properly.

Most of our chain is purchased in bulk and kept in central locations, from which it is requisitioned by the using departments. The storehouses tag each lot of chain to show our order number and the supplier's name. We make our own slings, except where special rings or hooks are to be a part of the assembly, in which case we may order the sling made up by the chain manufacturer.

Our first inspection of chain is made upon its receipt by our Stores Department. Samples are cut from each size in each order and tested in the laboratory to determine that they meet the chemical and physical requirements of A.S.T.M. A.-56. If the chain meets these requirements, a written acceptance is sent to the Stores Department, who thereupon send the chain to the central stores location for which it was ordered, which is generally the Blacksmith Shop. Here the chain inspector gives it a very careful visual inspection before indicating final approval of the chain.

The Blacksmith Shops make up slings of the length ordered by the using departments, the finished slings being inspected to assure proper workmanship on end rings or other attachments, and, in the case of paired slings, to insure that they are of the same length.

We have found that a system of records, which will show the identity and history of each sling, is not difficult to keep, and is indispensable considering the information and control of chain which it affords. Each sling is stamped on the most protected surfaces of the end link or hook, in two places, with a letter to indicate the department for which it was made and a serial number. The sling number is entered on a 5"x8" file card which provides space for recording (1) the name of the department, (2) order number under which chain was purchased, (3) size and

length of the chain, (4) description of hooks or other attachments, (5) purpose for which chain is used, (6) proof test load, (7) maximum safe working load, (8) weight, (9) date placed in service, (10) dates when repairs were made, with description, (11) dates when heat treated, (12) date when chain was discarded and (13) number of days total service. This record serves as a systematic check on the inspectors and also permits us to judge which chain manufacturer is giving us the best chain.

After being placed in service, the slings are periodically inspected, the frequency of inspection being determined by the severity of the service under which they are being used. Chains carrying heavy loads of hot steel may be inspected every few hours, while chains carrying lighter loads will be inspected less frequently. In some locations chain may be inspected only once a month.

Weekly reports are made by each inspector showing the number of chains under his supervision, number inspected, number of new chains put in service, number and nature of repairs made, number of chains annealed and number of chains scrapped.

Inspectors, in their journeys through the plant, are instructed to watch chains in service and to instruct the workmen in the proper use of chain slings. The workmen themselves, in a sense become chain inspectors and are taught that chain must be kept free from kinks or twists, must not be dragged over hard material, must not be pulled out when caught under a load, or otherwise abused. They are cautioned to use slings of the proper size and length for the work handled, to avoid overloading and sudden or jerky application of load when making a lift, and to see that loads are properly seated in the hooks or carriers. The inspectors also watch to see that chains are kept as clean as possible, since an oily or greasy chain not only is difficult to handle, but will collect dirt and grit which will cause undue chain wear.

At the proper inspection intervals, the chain inspector will lay the sling straight along the floor and carefully examine each link, using a hand glass if necessary, to detect flaws. Slings which have become too dirty may be washed in caustic soda before inspection. If flaws are suspected which may not be readily visible, the surface of the link may be coated lightly with oil, which penetrates the flaws. The excess oil is wiped from the surface, which is then coated with whiting. After the whiting had dried, the oil will appear through it wherever there are surface flaws.

The inspector will look for (1) flaws, cracks, gouges or corrosion in the weld or body of the link, (2) cold work as evidenced by a peened, battered, or polished appearance, (3) worn spots, measuring the diameter if necessary and (4) elongated links, measuring the length of the chain and matching it with its mate, if it be one of a pair. Questionable links may be up-ended on an anvil and the upper end hammered, which will produce cracks in excessively cold worked links and open up defective welds.

As previously mentioned, the chain inspector decides what repairs are necessary. A car seal is placed on the end of the sling to indicate that it has been taken out of service and the inspector sees to it that the chain is delivered to the Blacksmith Shop for repair or heat treatment. No make-shift repairing, splicing of straightening in the department using the chain is permitted. Chains that are to be discarded are immediately cut up into short lengths and placed in the scrap bin, so that there may be no chance of a workman carelessly picking them up and using them. Chains which have been repaired are inspected to see that repairs have been properly made, before being re-issued for service.

Good house-keeping is well worth while in storing chains. Each department is provided with a locker in which idle slings may be stored away from dirt and weather as much as possible. This also minimizes the chance of one department picking up and possibly improperly using chains belonging to another department.

Some of our departments believe that they obtain better chain life by "giving the chain a rest," rather than working it constantly. Since each department has a certain number of spare chains, this is not a difficult program to follow. The idea may have some merit from the standpoint of fatigue phenomena and is mentioned as a matter of interest.

Mention should be made of the various attachments which may be a part of a hoist chain assembly. Hooks, rings, special links, spreaders, tongs, or special carriers, such as sheet pack carriers, are examined for flaws, deformation or wear with the same care as are the chains themselves. Special attention is paid to bolted or riveted sections to detect any bolts or rivets which may have become loosened or worn. Necessary repairs are made in the proper repair department.

In conclusion, I have described to you a chain inspection system which is adequate for any large user of chain and may be modified to adapt itself to the needs of the small user. It functions smoothly with an alert crew of inspectors and a working crew educated to the idea that good slings, properly used, are their safest tools. The system is one of the best safety measures a shop can adopt. It will insure the receipt of good chain from the manufacturer and that the chain will deliver its maximum of service, with least possibility of damage to material handled or to shop equipment and with least hazard to workmen.

Welding By The Shielded Arc Process

By H. M. DOWNING
The Lincoln Electric Company, Chicago, Ill.

Presented before the Chicago District Section of the A. I. & S. E. E., May, 1933.

Typical of the rapid progress of American engineering are the advancements made in the art of arc welding during the last few years. It is probably not over-emphasizing the importance of this progress to say that more far-reaching developments have been made in the last three years than in the entire history of welding up to that time. Advancements in technique, welding machines and in electrodes have served to improve markedly weld characteristics; have increased welding speeds; have cut costs to a fraction of their former figure; have made possible the welding of many metals and alloys not previously considered as weldable.

For many years little attention was paid to the electrode or welding wire used with arc welding machines. Gradually it was realized that the electrode was just as important in securing sound welds as the welding machine. Instead of bare electrodes, wire was coated lightly, some with a powder and some with a binder which made the coating adhere directly to the rod. For the most part the quality of welds made with these lightly coated rods was not materially improved, but the arc behavior was. Such welds had a tensile strength of 40,000 to 50,000 lbs. per square inch and a ductility of from 2% to 8% elongation in 2 inches. Slag inclusions in the welds were rather common. So were gas pockets. (You will note that the past tense is used in referring to these lightly coated electrodes. This is because they were once considered standard. While they are still used extensively today, they are generally recognized as "second best").

With the advent of the shielded arc process of welding, welding characteristics were changed materially, as we shall soon see. While there are several types of shielded arc welding, including the automatic process, the commonest involves the use of special heavily coated electrodes, such as "Fleetweld", manufactured by the company with which I am connected.

In order to make clear why it is possible to achieve much better welds by the shielded arc process, let me first explain something about what takes place within the electric arc while welding. It is common knowledge that the molten weld metal as it is being deposited has an affinity for oxygen and nitrogen. Since the arc stream is maintained in an atmosphere composed chiefly of these elements, oxidation proceeds at a high rate during the passage of the weld metal from the electrode to the arc. In this way oxides and nitrides are formed in the weld. It is the presence of the oxides and nitrides in the weld which impair its strength, ductility and resistance to corrosion.

If the molten weld metal is protected from contact with the atmospheric oxygen and nitrogen during the process of deposition the welds so produced will be reasonably free of oxides and nitrides. Thus an arc completely shielded, such as that shown in Fig. 1, deposits weld metal superior to that deposited by an ordinary arc. The coating, which has a thickness of 10% to 12% the diameter of the rod itself, is carefully manufactured so that it is of uniform quality and its action under like circumstances is always the same. The coating performs three primary functions:

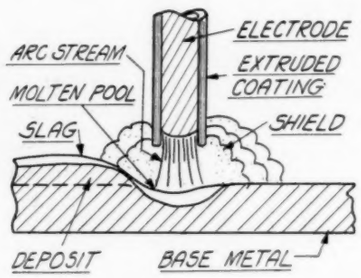

FIG. 1—With a heavily coated electrode, the molten weld metal is protected from the oxygen and nitrogen present in the atmosphere.

1. It adheres to the electrode.
2. It protects the molten metal from the atmosphere, as stated above; it breaks down from the heat of the arc and forms protective and reducing gases which exclude the atmosphere from contact with the minute globules of weld metal.
3. The coating is consumed more slowly than the steel electrode and forms a slag deposit over the weld which further precludes atmospheric oxidation and also slows up the rate of cooling of the weld deposit.

All of these characteristics are essential. A shielded arc electrode must be so manufactured as to perform these functions under all conditions.

The extent of the superiority of a weld made by the shielded arc process can best be judged by comparisons of the structure of weld metal and physical and chemical tests.

Welds produced in a shielded arc show tensile strength of 65,000 to 75,000 lbs. per square inch as compared to the 40,000 to 50,000 obtained with a bare or lightly coated electrode. Specific gravity of a shielded arc weld is greater than 7.80. The ductility, measured by the elongation in 2 inches, is from 20% to 32%, with an average of around 26%.

It would seem that a welding electrode that would give such radically different results from that to which we had become accustomed would require different arc characteristics. First, the electrode itself is positive instead of negative. Second, a longer arc must be maintained; and third, a higher current is necessary for a given size rod and a much higher output of wattage is required of the generator. All of this in turn improves not only the quality of the welds, as spoken of before, but increases the speed of welding from 50% to 300%. Thus it must be borne in mind that the speed increase or rate of metal deposit is accomplished not at the expense of quality but with the quality very, very much improved over anything known before.

The necessity for a welding machine of different arc characteristics is apparent by considering the performance of the machine while welding with bare or washed electrodes and shielded arc electrodes. This can be shown by observing an operator welding with bare electrode and noting that a small variation of the arc length causes the electrode to have a tendency to freeze to the work, or the arc be extinguished by lengthening of the arc. This is a short arc performance.

You will also note that this same operator when welding with the shielded arc electrode will weld without interruption, although the variations in the arc length are exactly the same in either case. This is a long arc performance. Therefore, it is necessary to provide a machine with proper arc characteristics. This has been accomplished by increasing the voltage and reducing the fluctuations of current for a given change in arc length.

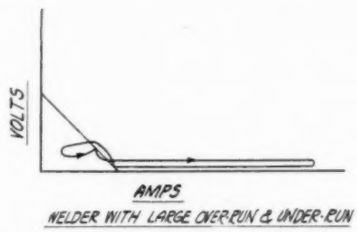

FIG. 2—Welder with large over-run and under-run.

1. By providing a machine with more nearly constant current characteristics.
2. By reducing the over-run and under-run of the current.

As indicated in an oscillograph, some types of machines have a current over-run as high as 500% in changing from the condition of welding to short circuit. In other words, an operator using 300 amperes might have an instantaneous current of 1500 amperes upon approaching short circuit. A well balanced design limits this over-run.

This reduction of over-run has the following advantages:

1. Increases welding speed.
2. Increases current for a given size of electrode.
3. Reduces splatter.
4. Reduces porosity in the weld metal.
5. Reduces loss of electrode.
6. Decreases cost.

Under-run or decrease of current which is common to machines having excessive over-run, has also been limited in the new type machine. Excessive under-run, or decrease in current with a lengthening of the arc, causes:

1. Decreased speeds.
2. Improper shielding due to improper combustion of the coating.
3. Slag pockets in the weld metal due to improper burning of the coating causing it to flake off.

New type welders by limiting over-run and under-run of these transient currents permit a higher average current for a given size of electrode. This is readily apparent by illustration of the volt ampere curve.

Fig. 2 illustrates a conventional type of welder. Let us assume an arc of 300 amperes at 25 volts and show what occurs when a machine is short circuited —by sticking the electrode to the work, and also what happens when the short circuit is removed. The final current values will of course eventually be indicated by the voltampere curve. However, there are other transient values as shown by the oscillograph.

In the first case, as the electrode is short circuited the reactance in the circuit opposes the change momentarily, the surge then comes on the line as indicated producing a high instantaneous current. It is obvious that when this occurs the electrode is greatly overloaded and violent explosions will occur causing excessive splatter. To overcome this condition with ordinary welding machines it is necessary to reduce the average welding current.

In the second case, that is, upon breaking a short circuit and establishing the arc, an under-run occurs as shown by the line at the left of the volt ampere curve. This under-run current occurs as the arc is being established and lengthened, making it hard to reestablish the arc and also resulting in a chilling of the metal. An unskilled operator using a machine with excessive under-run will lose his arc just as soon as the short circuit is broken and only the most skillful can use such a machine.

It is obvious from examination of Figs. 2 and 3 that higher average currents can be maintained with the new type machine than with the old. With the new machine we are able to weld 10% faster with a given size electrode to produce a weld of equal quality. This means 10% higher currents should be used.

This description of the smoothing out of the peaks and valleys in the flow of welding current should not be confused with the time of current recovery of the machine. The time of current recovery, within reasonable limits, has but very little to do with the welding characteristics of the machine, although it has received a great deal of publicity within the last year or two.

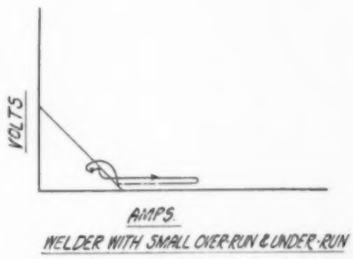

FIG. 3—Welder with small over-run and under-run.

From the foregoing rather brief description of the shielded arc electrodes and welding machines necessary for the best use of such electrodes it is apparent that outstanding developments have been made in welding in the last few years. It is also obvious that only with both the right electrode and the right welder can the results claimed for the shielded arc process be achieved. Used together and used properly, welds can be made stronger, more ductile, more resistant to corrosion—and they can be put down from 50 to 300 per cent faster with a consequent savings in cost.

Safety in the Steel Industry

By F. M. GILLIES
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Paper presented before the National Safety Congress, Monday, October 2, 1933.

The subject of Safety as related to steel plant operations, is one that has been exhaustively discussed by thousands of men each year. Each of its phases has been carefully considered, and were one to attempt to fully develop the subject, the time consumed would be too extensive; and so I will not try to conclusively discuss the problem of correlation of the subject with plant operations, but rather in a detailed way, treat with certain points which I believe are most salient at the present time.

The slogan "Safety First" has generally been adopted in the industrial fields in consideration of its employees. My experience has proved that this slogan has varying degrees of emphasis, and the causes for these are so deeply founded in human experience that to definitely establish "Safety First" as meaning exactly what the two words imply, is a task that needs the support of every individual employee from top to bottom of each industrial organization. The worth of such a slogan in industry is beyond question. It has found its place as a factor in manufacturing, from both a practical and economical viewpoint, as well as its ethical value.

Educational progress along the lines of more modern complex mechanical equipment and processes, has convinced us that human life and health must be safeguarded, and this can best be done by the proper employment of human intelligence which should be, and has, developed to a degree able to cope with the more complex problems, and this brings us to one phase of our subject, ,of co-ordinating safety with plant operations. This is a management problem equally important with many others, and only with this belief can results be obtained.

The plant head of a steel operation must first definitely establish himself as being totally behind the safety movement before sound progress can be hoped for. The varying operations of a steel plant which necessitate the employment of large numbers of employees require the study of a specialized and trained man to have charge of the plant's safety. This man must then have the full confidence and backing of the operating management. Items and policies that come to the management for decisions, are often expensive, and at times academic in their substance compared to other operating situations which appear more important because of their effect on the balance sheet, but they are none the less to be given equal consideration and importance by the management if the plant is to be made a safe one to work in.

We must first set up the safety director as one channel for safety promotion and establish this office as the individual who develops the safety plan of operation in the plant, maintains the records, inspects equipment and oversees its safe-guarding, as well as establishing through co-operation with department heads, all arrangements for safety education of the men and certain supervision over the meetings. This plan is generally adhered to at most plants. Then there is the other channel that operates directly from management to men, whereby the connection of manager to department head, and department head to foreman, and from foreman to working individual, establishes a safety code which is just as well founded and as perfect in its workings as any plan of operation in the finishing of a rail, or the perfect production of a full finished sheet. The manufacturing of the perfect product should be no more considered than the attainment of a perfectly ordered group of workmen who carry on from day to day efficiently and without injury. How can this be done? I have here some plans, most of which are in practice at one plant or another, and some that appear to be somewhat too detailed to be practical. They are ideas, however, and to further progress in a field in which there has been improvement, but which is still far from perfection, the imagination has to be employed from time to time.

One of the major problems towards instructing plant personnel in safety is to have some definite means which will assure the management that the workmen are thoroughly instructed in such a way that they can keep clear of the hazards that they must encounter daily. The problem distinctly presents itself in the steel plant where the makeup of the roster of employees consists of such a great number of nationalities with varying degrees of education and intelligence. Assuming that the great majority of the foremen are Americans, and only speak the English language, and conceding the fact that the foremen must be instructors, it is obvious that unless the particular foremen have convenient interpreters, much of their instruction will not be perfectly understood. Therefore, before we extend any program of safety with success, we must successfully find some way to have it understood. The plan of printing signs in various foreign languages such as Polish, Hungarian, Slovish and Spanish, has been in vogue for many years, but these signs must of necessity only deal with danger warnings in prominent locations, and the rest must be understood by the men as best they can. Most of the major steel plants have gotten up their book of safety rules in the languages of the men who makeup their greater percentage of foreigners, but this again only expands the idea of signs, and at the best does not deal with detailed work and temporal situations. We are definitely confronted with an obstacle here, and in my experience, a great many accidents occur from this cause alone. This is not entirely one-sided. The effect on the foreman who is giving safety instructions to ears that he knows are recording imperfectly, is most discouraging and influences an attitude of doing the best he can and hoping for luck. Even in the case of an available interpreter, the second-hand instruction is very often distorted, and so from both angles we recognize a problem most difficult, and before thorough results can be hoped for, it must be overcome. The simplest and best way out of this is to restrict employment to only

hiring men who speak English. On the other hand, with the available labor market in the steel industry, and considering the irksomeness of some of the work, it is plain that we cannot hope to have entirely English-speaking men as employees. Therefore, I believe that the problem of the management is an educational one and each steel plant should carry on a program to teach the Engiish language to those foreigners who have not mastered it. This should not be expensive and to my mind is primarily essential before the safety program can be carried out. This problem of English classes can be turned over to the safety director, and personnel for teaching can be readily and economically obtained. Limiting the employment to English-speaking people, or those who are willing to attend classes, where they can learn English, gives any plant a good control over this situation. This is not a novel idea, but I do not know of any steel plant that has made the learning of English compulsory, and until this is accomplished, safety programs and all kinds of instruction will never be thoroughly developed.

Assuming now that we are on a basis where every employee is fundamentally educated enough in our language to understand our various methods in closing in on carelessness and all of its kindred associations, we can set forth with a program from all angles. The first and most popular angle, is to bring safety to the front so that along with the other duties of the workmen this subject envelopes all phases of his daily work. Some method must be used to make the man think safety many times a day. This accomplishment can best be brought about by one of our foremost American institutions —advertising.

Advertising has accomplished so many great things in our industrial and mercantile world, and has proven its worth so positively, that not to exhaust its possibilities and to thoroughly infuse it into any program which is difficult to promote, is a serious mistake. The type of advertising most familiar to us is the sign or the poster, but this can be definitely overdone. One sign placed at a strategic point, or where it would be generally observed, is worth a hundred cluttering up a wall or a mill entrance. We only have to relate our impressions in regard to advertising observed on the main motor highways, to conclude that no one advertiser stands out, and although we know that there are any number of Inns, Taverns and Barbecues five hundred yards farther on, it is seldom that anyone of them is convincing enough to draw our trade. Therefore, the conclusion must be that the signboard method should be used discriminately, and the advertising derived to gain our point must come from the sign itself. Here we may attract the eye and clinch the memory by unusual color combinations, unusual wording, or unusual shape. The obvious is rarely interesting, and therefore to attract and to hold the attention all signboard methods of safety advertising should be somewhat out of the ordinary.

Bulletin boards, which are generally placed in every department in each plant, had somewhat of a spree in recent years. The idea displaying cartoonists' posters depicted some safety slogan, or some possible cause of accident; or in some cases the result of an accident, where is shown the disgruntled workman sitting in a wheelchair on the front porch swathed in bandages, with his underfed children and overworked wife in full view, while his bright smiling friend who was the safe worker, whom the cartoonist does not even allow you to guess about, but labels, passes by to his work whistling with a full dinner pail. Cartoons of this sort, while interesting in many cases, are to my mind somewhat ineffectual in remaining uppermost in the adult mind. In other words, we, as manufacturers, would hesitate to drive home any principle in regard to the manufacture of any product that we might be turning out, in a similar way. Again, the novel idea of attracting the employee to the bulletin board to see news service photographs of Babe Ruth in action, Charlie Lindbergh departing from Roosevelt Field, or the new fat woman with the Ringling Circus, has been popular in recent years, the idea being to attract the employee to the bulletin board in hopes he will read the safety letter which contains various statistics and figures thereon. This method is not to be entirely condemned, but I am afraid that the results obtained are not unusual, for too often on viewing the bulletin board set up in this way, it only brings questions as to the relative merits of the various home-run hitters, or whether Lindbergh's ability surpasses Jimmy Doolittle's, and various other foreign subjects that might be brought on by the photographs. Undoubtedly by this time, the conclusion of the National Safety Council, and the various bulletin board services, will ask what substitute we recommend for these. My recommendation in order to get the same attraction, and to more quickly arrive at my subject matter—Safety, is to drive from a different angle. Photographs can be used, large, clear photographs properly gotten up of various types of work done in the department in which they are exhibited; one picture showing the improper way, the other the safe way of men actually employed in that department. This plan utilizes one of the best ways of promoting newspaper sales that one of the large newspapers in Chicago has employed in recent years. People are always anxious to see themselves in photographs. That in itself should attract men to the board. Once looking at the photograph, they cannot help but observe the safety lesson graphically shown thereon. The idea of promoting personal interest by turning over part of the bulletin board for a week's time, or a month to various groups in a department to make their own bulletins, never fails to attract and to interest the employees. This, merely because it is of their own making, and strikes more intimately than the drab statistics that usually appear there. The bulletin board affords numerous possibilities, and the department head should make enthusiastic use of it.

The safeguarding of men and equipment, in order to be properly controlled in each department of a large steel works and to work smoothly, must be **uniformly** adhered to. To have especially rigid requirements we will say in the Coke Plant or Transportation Department, and to have less rigid standards in the Blooming Mills, brings about an unsatisfactory plant condition. It is true that we should not expect this condition with the proper supervision of the subject on the part of the safety director, but notwithstanding, I am sure that the experienced manager knows that this condition can exist in spite of a good safety man at the head of the department,

which emphasizes the point I wish to make that the management-to-man channel is the more important one through which to work to obtain thorough results. Even with the management's conscientious effort on the safety end, the difference between department heads in understanding and conscientiousness will bring up differentials in safety efficiency; then in turn from the department head to the foremen still increased variation is possible until we can definitely say that it is not uncommon to find quite a variation between departments in efficiency, and even different shifts of men guided by different foremen in the same department.

These variable results are unsatisfactory generally to proper handling of the subject because dissatisfaction arises among the working personnel who feel that they are unneedfully oppressed in the strictly run department in comparison to their friends who do not have to toe the mark as closely in the more lax department. Assuming that it is necessary to discipline for safety infringements, the severity of discipline will vary and this again breeds dissatisfaction with the stricter management.

The men who are to be disciplined rarely feel that such action is proper and deserving, and if they know that like infringements are less drastically handled in other parts of the plant, naturally they feel that they are not being treated fairly. All this brings an antagonism to the general safety program and makes the problem of progress greater. The best way to eliminate these irregularities is to **standardize the foreman's education** on the subject of safety by carrying on a Foreman's Training Course. This has been done by a number of steel companies and I believe gives excellent results. However, a point of discussion does arise as to what kind of a course to give and how often to repeat it. We all know that the repetition of the same course each winter session is not a good plan, for once the foremen have completed it they do not feel the need of going over it again and I don't blame them in feeling that a repetition is distasteful. If the course is repeated annually for new men who have been advanced to foremen positions, then with altering conditions we lost the contact with the older foremen, and so here we have a problem for the plant management.

I believe that for six weeks of every year we should maintain a Foreman's Training Course and the subject of Safety should be treated with each year, but I do feel that we cannot treat entirely with Safety for six sessions and make it sufficiently interesting to maintain an enthusiastic attitude. I therefore suggest a general foreman's course each winter season which treats generally with the business of acquainting this supervising personnel with all the intricacies of the company's business and intimately informing them of all the varying commercial problems that arise from year to year.

One of the sessions can be given entirely to Safety, while all of the others will indirectly affect safety by increasing the general interest and enthusiasm of the individual foreman in plant problems. The foremen should be made to know that they are the actual contact operating heads of the plant, and a course should be designed to give them a thorough knowledge of what the operating heads should know to be able to handle their jobs with intelligence; this should make their responsibilities more apparent and their jobs more interesting, and with the interest alive and active, the influence in carrying on safety work must naturally improve with this group and they in turn will impart this to the men by better management from all angles. In this way we can standardize safety practices and we then can hope to have a well balanced application of safety effort in all departments.

DISCIPLINE

One of the most generally used and most practical methods of enforcing safety is by disciplining those who are proven guilty of infringement of the safety rules, or have in some way shown themselves to be careless. Just like any other plan for law enforcement, the problem is to insure strict adherence to the law, and all punishment is designed to gain this result, or to serve as an example to others who may at times feel that it is unnecessary to live up to the law. It would be pleasant to be certain that an intelligent warning to a man who had violated a safety rule would guarantee against a repetition, but experience has proven that too often this warning has had influence for only a brief period, and the same infraction later results in an accident. Although there will always be considerable faith in the efficiency of the warning to better guarantee against law violations, discipline will of necessity be somewhat more dependable to develop the proper respect for safety regulations. Even this may miss its mark of successfully eliminating bad practices, but we can truthfully say that it at least emphasizes the subject. My prior belief is that education is our only hope for the safety millenium and perfectly safe performance of all work can never be realized prior to the time when our safety education is complete, but in the meantime positive and direct punishment seems the only practical plan. We have only to look at crime in general and the means of coping with it to know that severe punishment does not eliminate it, but I am sure if there were milder methods employed, crime would be more rampant. We can't put a man in jail for a safety violation, although I can truthfully say it has been deserving of it in my experience, but we can punish to what we feel is our best extreme, and that is by laying men off. It is simple for a supervising head to send an employee home for several days or a week. It has more authority than a judge because there is no possibility of appeal and so with the exercising of this authority, must go considerable conscientiousness of judgment. A working man disciplined unjustly will not become a safer worker, and therefore the management must take a hand in the administration of punishment. Conditions among a group of men under a foreman's supervision may establish a situation where without sufficient regard from all angles, a decision will result in unfair punishment, and so when discipline is used, to make certain that it has been well considered, the department head should be brought into it so that his more mature judgment will guarantee against possibility of unfairness. If all the precautions are taken to eliminate error in judgment, then I am in favor of cold, hard discipline as being not the most satisfactory, but the best method of safety law en-

forcement I know of. We have a regulation in our plant requiring the department superintendent to personally investigate every minor accident that occurs under his charge. (A minor accident is one that does not incur any loss of time by the injured man). This investigation brings in the foreman under whom the accident occurred, and also all witnesses. In this way the department head has a thorough knowledge of the accident and he orders the punishment for the offense, and this guarantees us against possible unfairness. Foremen who discipline for carelessness of rule infringements must make out a report and forward it to the department head for his approval. In this way we feel certain that each case is given intelligent consideration before being acted upon.

I have often wondered when, as a department superintendent, what steps I would take to make certain that no accident would take place under my charge if the order had come out from the General Offices that if during the month an accident took place that meant a loss of time, I would be given a month's vacation without pay. In striving with the problem of making men look after themselves better, and eliminating safety hazards, one often wonders if they are doing all that is possible to do. If the order came out, and not having a desire to vacation without pay, several things would happen. First I would naturally think that the management was rather rough, then I would set about cautioning every one in the department that if anything happened, that before I started my vacation there would be several others handed out, and undoubtedly to get through, the month production activities would be carried on slower and surer so as to play safe. Although this might result in accomplishing the thing we are trying so hard to do, for certainly the subject would be stressed, and although production might be slowed down temporarily, ultimately more speed could be accomplished while working entirely safely, and perhaps at the end of six months of such an autocracy, ground would have been gained that was never thought possible to advance over. Then I have wondered if a somewhat milder degree of this ultimatum would not serve. Any accident transpiring which results in a loss of time and has happened as the result of poor supervision, poor instruction, equipment not properly safeguarded, or from other carelessness that could have been avoided, would call for a two weeks dismissal. This I feel would work and work well, but again this is drastic on the department head if he is expected to manage anything but the safety of the department. Often his duties prevent him from daily contact with all parts of his department and physical changes that come up daily might not be known by him and facts of an accident, although within the code of his responsibility, could not be fairly attached to him. There are other good reasons of management and the psychological side makes this impractical, but it has its arguments which I believe can be used farther down the scale of management.

The foreman has more influence on safety progress than any man in a working organization. The foreman is our best safety bet. We must look to him to do the work, to know the men, to note the regard for safety in his men and to observe the conditions that his men work under. We must depend on the foreman to get our results and to properly make certain of them. We must penalize him for failure to carry this end out. Here is our best spot to put the penalty of discipline, for accidents that occur under him that are caused by proven carelessness or laxness on his part. This will awaken him to his responsibilities and produce results. Knowing that plant management stresses the foreman's responsibilities so strenuously, has a tendency to cause the management to nullify discipline if there is a way out, but this should not be done. If the foreman is the right sort he wants to do his work as well as it can be done and if he has neglected the safety phase it should be forcibly brought to his notice, and with that in mind, our method of dealing with lost-time accidents is to have them investigated by the Assistant General Superintendent of the Plant. The investigation is complete and thorough, and fair, and if in the findings the foreman is proven negligent, he is disciplined. Providing that the utmost fairness is used, this, I believe, has and will accomplish results, but as I say here, and as I have said in these investigations, it is certainly not the most satisfactory method but appears to be the most practical and efficient at present.

The steel industry for many years has not had a very high standard of qualification for employment. While the department head and his assistants were naturally favorable toward employing the most proficient man, they could for the job, years of immigrant labor, plus long hours, and much work which was quite irksome, had not developed a very good level on the standard for the general classification of semi-skilled and unskilled workmen. These requisites have improved somewhat. I believe since the inception of the 8-hour day in 1923, but our methods of selection I am afraid have continued along on much the same basis which were in practice for the preceding thirty years. With the restriction of immigration, which has cut down the number of acquirable so-called greenhorns, the general intelligence standard has improved, but only because the immigrant had become more used to our ways and had accumulated more general intelligence. He also learned to speak and understand our language better each year and this again influenced his intelligence rating. The influx of Mexican labor in some of the steel producing centers was not such a handicap because the average intelligence of these people that have emigrated to the States, shows that 80% of them can read and write their own language, which is superior to the immigrant from northern Europe who came to this country in such great numbers prior to the war.

Assuming that the intelligence rating of the average employee has advanced in the last ten years, still our employment methods permit the employing of some rather retarded mental developments, and I believe we will all agree that every time such a man is hired the company acquires a risk far greater than that normally assumed with one of so-called average intelligence. Therefore, I am of the belief that some sort of a test should be required. It would not necessarily eliminate many but would give a fair rating of common sense and at least eliminate those who were outstandingly backward, who as a class contribute greatly to the group that have accidents.

Along with the mental side must be considered

the physical side. A man in bad health from one cause or another or one with disabilities not easily detected, is more prone to get hurt than one well equipped and in good general health. There has been quite a variation in this regard in the various large plants, as far as requisites are concerned. Some have no examinations, others only cursory ones, and some I understand are quite thorough. While I question the value of a very thorough examination, I believe that a general examination should be held which will bring out physical defects, or conditions such as bad eyes or impaired hearing, bad heart or lung condition, or infectious diseases which bring about general run-down conditions. Refusing employment to men who cannot pass an examination of this kind, cannot help but have its beneficial result in the safety record.

There might be a general objection from the supervising personnel who are not used to these formalities. They might consider them somewhat academic, but objections of this kind are not backed up by the best judgment, and once the practice is instituted, the general benefit derived would in my mind win them over promptly.

REWARDS

The practice of rewarding departments, groups, or individuals who have been successful in completing a period of time in which satisfactory or outstanding safety records have been made, has been in practice to a lesser extent in some industries. During the recent depression I am afraid this feature has gone by the boards along with many other bonuses, etc., made necessary by strict economizing.

I am of the opinion that there is merit in the plan generally, for we know that one of the greatest fundamentals in securing unusual performance is a reward of one kind or another. Cash rewards are the only kind I consider. The idea of a watch fob, or other decorations, are all right as emblems and may distinguish the receiver of the reward, but the money will secure more certain results. The school boy can feel amply rewarded by receiving his school letter or insignia as a reward for proficiency in sport, but the workman has different responsibilities and different criterions and is most naturally interested in cash. It is impractical to attempt to distribute a nominal sum to a large group of employees, for unless extreme generosity is used, the increment to any one workman would be too small to have the desired effect and so I recommend that those men whom I have said previously are our best safety bet —the foremen, should receive the reward. We insist upon his safety work paralleling the efficiency and quality of his production responsibilities. He is paid for his production possibilities, and if errors or failures are to be penalized by discipline, unusual performance should be rewarded in some way. By this method I believe we can feel more fairly about insisting on no failures when it comes to observance of the safety requisites.

CONCLUSION

As you no doubt will agree, my treatment of the subject of co-ordinating plant operations with safety management, has been rambling. I have made no attempt to set up a working safety plan for an average plant. In doing this I would have necessarily gone through much conventional data which is now generally in force and has proven its worth. I have attempted to treat on the phases that are directly in the plant management's hands, and although the ideas are not original in most cases, they all to my mind have worth if we are to continue to wage the battle against accidents. We will all agree that much progress has been made in the industrial field and now to go farther into the enemy's territory, our methods must be more intelligent, better planned and more detailed. The protection of humanity against tragedy, hardship, poverty and the numerous allied difficulties that accompany accident, must go on, and the plant management which does not day by day give time and thought and push to the forward movement of this battle, will be left behind in the march forward and will not have the satisfaction of knowing that it has made better the chances for each man who enters its gates, to pass out through them again, sound in life and limb.

What The Steel Industry Is Thinking About

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The information and data contained in this resume has been secured from the engineering executives of the Iron and Steel Industry and definitely reflects the class of materials which will be purchased from equipment manufacturers of the United States. You will note by carefully analyzing the statements made that a huge potential business exists for mechanical, electrical, lubrication, combustion and metallurgical products required by By-Product Departments, Blast Furnace Departments, Open Hearth Departments, all types of Rolling Mills, Power Houses, Transportation Departments, Production and Maintenance Shops.

By-Product Coke Plants

During the recent ebb in the business tide, production was stopped on many batteries of coke ovens. Some of them were kept hot, while others were left to go cold. Particularly in the latter case, a considerable repair program is needed. Contraction and expansion during the cooling and subsequent heating has opened up oven walls to an extent depending largely on the type of oven and a general tightening up is necessary for satisfactory operation.

Disposal plants to take care of phenol and other objectionable wastes that now pollute lakes and rivers.

Utilization of the heat in the coke as it comes from the oven to make steam by Dry Quenching Process.

Installation of equipment to extract more of the By-Products.

Many by-product and benzol plants have undergone the ravages of idleness during the past several years and general overhauling of stills, pumps, turbines, boosters and piping are required before economical operations are resumed.

The use of blast furnace gas for heating coke ovens must necessarily receive attention in any large plant striving for economical fuel application.

Blast Furnaces

Low productions are obtained either by blowing the furnace for a period, say four hours, alternated with an equal period during which the furnace is merely "fanned" so as to keep gas from backing up into the blast system or by slow blowing using as little as 40% of normal blast volume. The latter method seems to have the preference and observations on this method indicate:

1. Great reduction in coke loss by solution so that coke rate on slow wind is not greatly effected.
2. No increase in Tuyere loss or lining deterioration.
3. Very low flue dust production.
4. Stock builds on to furnace walls around the bosh, adapting lines consistent with the low blast volume.
5. A higher blast temperature may and should be used, as the furnace tends to work cold, and the iron may be cold, though chemically uniform.
6. Tuyere size must closely follow blast volume.
7. Changes in blast volume must be very gradual.
8. Surplus gas is reduced.

The use of leaner ores, and similarly, of reclaimable piles of ancient vintage flue dust, is receiving attention and material of this type is being mixed with other ores in many plants, at the expense of somewhat higher consumptions of coke and limestone, but with satisfactory results.

The lining of many furnaces have disintegrated due to idleness and extensive repairs are indicated here. Some of these furnaces will be enlarged, the increased capacity thus obtained making possible the elimination of small obsolete units. These enlarged furnaces will be completely modernized and electrified throughout.

In the drive for economical production blast furnace stoves come in for their share of improvement. Heating surface is increased, with gas passages proportioned to the volume of gas passing, so that stove capacity is increased, making operation possible with fewer stoves. Improved combustion equipment on stoves has reduced their gas consumption materially.

In general, the physical condition of auxiliary equipment has suffered greatly and extensive repairs to pig machines, ore handling machinery, sintering plants and transportation equipment are required. Gas cleaning equipment will undergo marked changes, due to the finer degree of cleaning required by the increasing application of mixed fuels to steel plant heating. Attention is being given to precipitation of blast furnace gas by electricity.

Considerable thought is being given to the substitution of Mixer Type Ladles for old type open ladle.

Many experiments are being made for the further utilization of Blast Furnace Slag for insulation in various forms.

In the future the small blast furnace will become obsolete, a new furnace of 1000 tons capacity will be built with the resultant increase in capacity of all auxiliary equipment.

Open Hearth Department

As previously mentioned, the use of mixed gases is receiving more consideration, as the blast furnace gas thus used replaces high priced fuels, with ordinary steam coal taking its place. Also, with proper mixing equipment, the mixed gas system provides a means of adjusting the quality of the fuel to the particular requirements of each period of the heat, yet, once set, gives a fuel of constant quality.

Installations of combustion control and instruments on open hearth furnaces are increasing, and tend to take furnace operations out of the "rule of thumb" class and to make easy duplication of results. It has been proven that open hearth slag will absorb sulphur from a reducing atmosphere containing sulphur. Hence, with most fuels, the importance of controlling the furnace atmosphere is at once apparent.

Open Hearth furnace design is at last receiving general (and tardy) attention. Based on the correlation of existing data and practice, various attempts are in progress to draw conclusions which will nationalize furnace design. The way is long and rough, and we have not progressed far, but a start has been made.

Furnace life is improving and will continue to do so as a result of control installation, better furnace design, and the gradual development in refractories. These factors, coupled with the wider use of heat insulation for all exposed wall surfaces including the roof together with insulation of hearth and gas flues are producing a gradual reduction in fuel consumption.

Steel making practice has been the subject of considerable experimental work in various quarters, and some very interesting results have been obtained. The present need is for alert, progressive steel makers, to apply the experimental results to actual open hearth practice. It may be safely predicted that the future will bring methods of scientific control to replace the guess-work in open hearth steel making.

A general trend is toward the enlargement of open hearth furnaces. In most cases, this move requires the revamping or renewal of a number of shop auxiliaries, such as ladles, ladle-cranes, charging machines, slag ladles, teeming equipment, etc.

For the more efficient use of roof brick in open hearth furnaces, the suspended roof arches are receiving considerable attention.

Rolling Mills

Demands of steel buyers have necessitated much improvement in rolling practices. Many manufacturers are using hot-rolled stock for jobs formerly employing cold-drawn stock. The close tolerances thus

imposed on mills require improvement of various phases of mill design and practice. Developments are in progress in connection with precision rolling of bars and rods.

Shears and gauges require improvement so as to attain accurate lengths and clean cuts, without bending or kinking the bars. In some cases hot saws must be installed.

Greater accuracy is needed in mill screws and their controls so as to hold drafts and sizes closely. Experiments with screws and nuts of various materials are in progress, in attempts to reduce wear on these parts.

Roll passes have been the subject of investigation for some time, and considerable progress has been made in the elimination of hit-or-miss roll design. The same may be said of rolling schedules on blooming mills.

Composition bearings and anti-friction bearings are coming into use to a greater degree on all types of mills, from the bloomer on, and results point to lower lubrication costs, decreased maintenance costs, and closer control of sizes on the mill. The use of various lubrication devices contributes also to these results.

Demands for better surface on rolled steel products require better means of scale removal, as well as improved heating. Methods of scale removal lean towards the use of high pressure water streams, although compressed air or mechanical means are also used.

Heating furnaces are receiving attention so as to obtain thorough heating, with good scale conditions and without washing or burning. In many cases this calls for the installation of pyrometric, combustion and furnace atmosphere control and of course thoroughly insulated. There is much progress to be made here however, before the human element is removed from the heating operation as completely as has been done in modern sheet mill heating.

Use of photo-cells is expanding, and their field of application is broader. They are used for actuating the control of various mill equipment, scale breakers, and in some cases for gauging the length of the rolled product.

New developments in temperature measurement have brought forth pyrometers which will measure the temperature of hot billets in a very short interval, so that the temperature of a billet passing on the mill table may be made apparent to the roller.

General modernization in many plants calls for the elimination of much old hydraulic equipment, with replacement by electrical power, and there are some plants in which a great amount of electrification is in order, replacing obsolete steam equipment.

Sheet Mills

Perhaps the greatest strides in modernization are being made in sheet mills, where the trend toward two and three high mills equipped with automatic sheet catchers is quite marked. Included in these installations, and also in other plants, are modern continuous sheet and pair heating furnaces equipped with automatic temperature and atmosphere controls, wherein the human factor is a minimum.

The demand of the trade for wide sheets has resulted in wider mills, and requires wider furnaces for both hot mill heating and for the process heatings, normalizing and box annealing. With these wide mills, the importance of having the mills in good shape increases, and electric roll heaters are highly desirable.

A new design of box annealing furnace is under development, similar to the bell-type electric furnaces, wherein gas is fired through tubes of heat-resisting metal. These tubes act as do the resistors in the electric furnaces, but have the advantage that forced cooling may also be used if desired.

"Luminous burners" seem to be in the ascendency at present, and new designs on the market are producing excellent results on hot sheet mill and normalizing furnaces.

The use of heat resisting metals has expanded greatly, due to their application in modern sheet furnaces, but there are many places in the steel mill where these useful alloys may be profitably employed.

Miscellaneous

Many auxiliary departments are badly in need of overhauling and modernizing.

Water supply systems are in some cases inadequate and additional pumping capacity may be needed.

Some plants are in need of water softening equipment, and if not supplied will spend much greater sums in maintenance.

Many pump and air compressor stations should be electrified, eliminating uneconomical steam drives.

Boiler houses and powerhouses must be restored to good physical condition to regain normal operating efficiencies and many old plants require modernization.

Inter-plant transportation equipment must be overhauled and the possibilities of the electric, diesel-electric and gasoline locomotives must not be overlooked.

Continued research and developments for the purpose of producing high grade steel from low grade ores has been actively carried on. The near future will see the practical results of this work. It is predicted by many metallurgical authorities that its introduction will be as revolutionary as the invention of the Bessemer Converter.

The filming of steel, that is the transferring on steel sheets of the various wood grain structures and color decorations usually obtained by lacquering can now be placed on steel so perfectly that no veneer or layer of material can be noted.

Cleansing of steel sheets and billets with steel grit and without compressed air is receiving attention and study at the present time.

Better methods for burning low grade oils for heating and annealing furnaces will be developed.

Steel makers of the United States are watching closely the new metallurgical and mechanical developments in the new rotary process of making steel.

Another development which is being followed by steel makers is the rolling of molten metal. This experiment is being carried on in a prominent metal plant.

Rolling Mills of comparatively small capacity, which have been compelled to utilize old rails and other scrap as a raw material, will be interested in

a process for casting billets of the desired sizes direct from the output of a steel melting furnace. This process enables them to furnish rolled steel to meet the desired quality at a lower cost than can usually be obtained from purchased rolled steel billets.

Manufacturers of Cold Rolled Strip, will be interested to learn that a heat treating furnace has been built complying with the requirements of the ideal furnace i. e. to treat single thickness strips continuously at any temperature up to that which is limited by requirements of metallic electric resistors. Any desired finish from perfectly bright to raised scale can be secured by this furnace, which also requires exceptionally small floor space and because of its recuperative effect normalizes strip at 100% thermal efficiency.

Improvements in Sheet and Tin sorting.

The use of fabricated rolled steel in mill-building by Welding.

The use of Twin Motor Drive.

Improvements in Soaking Pit Practices.

Pertinent Points on Iron and Steel Industry Requirements

There are 743 rolling mills comprising 2207 stands which require complete electrification.

There are 1300 hand mills in the sheet and tin industry, the greatest percentage of which will be superseded by the 2-high, 3-high Sheet Catcher Type, and 4-high cold mills.

It is estimated that it will require approximately 2,500,000 additional electrical horse-power to completely modernize rolling mills in the Iron and Steel Industry.

Approximately $4,000,000 worth of crane track wheels will be required when the Iron and Steel Industry resumes normal operation.

$12,000,000 will be spent on Boiler House Maintenance in the first year of the Iron and Steel Industry's normal operation.

Over 2000 steam driven units will be superseded by electric driven units in the course of the next ten years.

At capacity operation the Iron and Steel Industry represents a market of $10,000,000 annually for lubricants.

747 Soaking Pits require overhauling in the Iron and Steel Industry.

$5,000,000 is spent for electrical maintenance in a year of normal operation in the Iron and Steel Industry.

Over a period of 25 years the Iron and Steel Industry has spent an average of $10,000,000 a year for expansion in electrical equipment.

$3,500,000 is the average expenditure for cranes during a year of normal operation in the Iron and Steel Industry.

Since 1927 the Iron and Steel Industry installed 1880 Coke Ovens, 2 Blast Furnaces, 69 Open Hearths, there were 50 Blast Furnaces remodeled and 63 dismantled. The Open Hearth capacity in ingot tons added was 6,253,100 tons. The Blast Furnace capacity added was 639,000 tons.

TRENDS IN MILL DEVELOPMENT

The barometer of progress made in rolling mills in the Iron and Steel Industry is indicated in the electrification of these mills. The following tabulation is furnished to indicate the rapid rate at which rolling mills are being electrified. These figures are for the main roll drives only.

Type of Mills	Total Electric Main Drive HP installed in 27 years	Total Electric Main Drive HP installed since 1927-1932 inc.	Percentage Main Drive HP installed since 1927-1932 inc.
Tube and Piercing Mills	160,000	106,500	66.56%
Rod Mills	108,000	45,000	41.66
Bar and Billet Mills	360,000	106,250	29.51
Strip Mills	385,000	222,000	57.66
Structural Mills	246,000	52,000	21.13
Merchant Mills	345,000	112,000	32.46
Plate Mills	154,000	37,000	24.02
Sheet and Tin Plate Mills	180,000	31,600	17.55
Sheet Bar and Skelp	163,000	51,000	31.22
Blooming Mills	305,000	135,000	44.26
*Cold Roll Mills	73,345	40,600	55.35

*Major installations only.

From 1927 to 1932 inclusive there was installed in the Iron and Steel Industry

17 Hot Strip Mills
83 Cold Strip Mills
6 Roughing Mills
33 Cold Sheet Mills
31 Hot Sheet Mills
2 Plate Mills
6 Billet Mills
5 Rod Mills (1 rebuilt)
18 Merchant Mills
11 Blooming Mills
18 Bar Mills
2 Edging Mills
9 Seamless Tube Mills
2 Lap Weld Tube Mills
1 Universal Mill
1 Universal Plate & Skelp Mill
2 Plug Mills
3 Skelp Mills
2 Hoop Mills
10 Hot Tin Mills
5 Cold Tin Mills
2 Jobbing Sheet Mills
1 Sheet Bar Mill
4 Butt Weld Mills
1 Billet & Sheet Bar Mill
1 Wide Structural Mill (including 4 mills)
4 Plate Strip Mills
1 Alloy Bar Mill
1 Push Bench
2 Tube Forming Mills
1 Structural Mill
1 Slitting Mill
11 Electric Weld Tube Mills

TO OUR 1933 IRON & STEEL EXPOSITION EXHIBITORS:

Since closing our recent activities we have received many oral and written compliments upon the success of our Convention and Exposition, and as you helped to make this possible we want to pass on to you these words.

Last week we received a letter from one of the leading Chief Engineers of the country who advised that for four years he has tried to secure authority to purchase a certain type of equipment for one of their steel mills but this was not possible until his superior saw this equipment in operation in our recent Exposition, and since that time the order has been placed. This example goes to prove the value of these Expositions, and we hope every exhibitor will reap largely from his investment in our Exposition.

Referring to our attendance, after a very careful analysis we find that a very large number of the highest officials of some of the largest steel companies of the country visited our activities, as well as their operating men, and we have developed many interesting figures, a few of which we give below:

Number of Steel Plants represented		116
Number of Industrial Plants represented		101
Number of Coal Mines represented		16
Analysis of attendance		
Representatives from Steel Plants	4,321	
Representatives from Industrial Plants	2,679	
Total attendance		7,000
Number of occupations, or positions, represented in attendance		201
Number of Coal Mine representatives in attendance		32
Number of States represented in attendance		23
Number of Cities represented in attendance		217
Steel producing tons represented in attendance		49,753,000
Total Horse Power represented in attendance		5,000,000
Attendance at Technical Sessions totaled		1,498
Attendance at Inspection Trip totaled		461
Approximate number of miles traveled by guests and members		400,000

Assuring you of our appreciation of your participation in our 1933 activities, and trusting you will be with us again in our 1934 Iron & Steel Exposition, with our best regards, we remain,

Sincerely yours,

ASSOCIATION OF IRON & STEEL ELECTRICAL ENGINEERS.

ITEMS OF INTEREST

PERSONNEL CHANGES

▲

J. Gordon Gage has been appointed General Superintendent of the American Rolling Mill Company, at Butler, Pa. Mr. Gage joined the American Rolling Mill Company in March 1910, as a wireman in the maintenance department at Middletown. He was made chief electrician in July, 1916 and transferred to Butler as superintendent of maintenance in July, 1929. On January 1, 1931 he was appointed works engineer, the position he held until his present appointment as general superintendent of the Columbia Division (Butler) of the American Rolling Mill Company.

J. GORDON GAGE

Mr. Gage has been an active member of the A. I. & S. E. E. since 1914. He has served on many of the national committees and at the present time is a member of the executive committee of the lubrication engineering division and the special magnetic control committee.

The membership of the Association extends to Mr. Gage their congratulations on his elevation to his new capacity and wishes him continued success.

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Lloyd Jones, until recently general manager of the E. W. Bliss Company at Salem, Ohio, has resigned to take the position of vice president of the Continental Roll & Steel Foundry Company with offices in the Grant Building, Pittsburgh, Pa.

▲

Charles F. Norton, former vice president and general manager of the Howell Electric Motors Co., announces his recent association with The Louis Allis Co., Milwaukee, in an executive sales capacity.

▲

L. W. Nash, who has been with the E. W. Bliss Co., in the capacity of chief designing engineer, at Salem, Ohio, has been appointed manager of the plant to succeed Lloyd Jones, who has resigned.

▲

C. H. Rose, assistant treasurer of the Youngstown Sheet & Tube Co., has been elected by the board of directors to serve also as assistant secretary.

▲

George H. Charls has announced his resignation from the American Iron and Steel Institute. He has opened an office in the Empire State Building, pending future plans.

▲

The appointments of Harold S. Broadbent as manager, and of DeNyse W. Atwater as assistant manager, of the Commercial Engineering Department are announced by A. E. Allen, vice president of the Westinghouse Lamp Company. The promotions come simultaneously with the appointment of Samuel G. Hibben as director of lighting for Westinghouse. Messrs. Broadbent and Atwater were assistants to Mr. Hibben during the 15 years he was manager of Commercial Engineering.

▲

F. F. Slick, formerly assistant general superintendent of the Edgar Thomson works of the Carnegie Steel Company, has been appointed general superintendent of that plant.

Mr. Slick has been in the employ of the Carnegie Steel Company since 1896 when he took his first position in the engineering department at the Edgar Thomson works.

▲

C. A. Colgate, 54 Vernon Drive, Mt. Lebanon, Pittsburgh, Pa., is now representing the Roller Bearing Company of America in the Pittsburgh territory.

▲

Steel and Tubes, Inc., of Cleveland, Ohio, announce the following changes:

Mr. A. V. Grove has been transferred from the Cleveland office to the Chicago office in the sales department.

Mr. R. E. Doyle is now sales correspondent in the Cleveland office.

Mr. J. F. Keeler is now sales engineer with headquarters at the Cleveland office.

▲

W. S. Gain, 416 Lafayette Bldg., Buffalo, N. Y. and E. A. Thornwell, 217 Whitehall St., Atlanta, Ga., have been appointed as district representatives of the Magnet department for The Ohio Electric Mfg. Co., effective at once.

▲

The Chicago office of the Ideal Commutator Dresser Co, in charge of "Motor Maintenance Equipment" sales, is now located at 618 West Lake Street, in charge of Mr. S. S. Callner, who is a Commutation Engineer.

WITH THE MANUFACTURERS

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The Welding of Aluminum is a beautiful 41 page booklet describing the various branches of welding in connection with Aluminum. This book represents a knowledge of welding Aluminum and its Alloys gained over a period of years by both practical experience and research work. The rapid growth in the use of Aluminum and its Alloys has brought about a demand for methods particularly adapted to the joining of these materials. Welding provides a means of making permanent joints and repairs on aluminum and aluminum and its alloys are given in the booklet, copy of which may be had by addressing the Aluminum Company of America, Gulf Building, Pittsburgh, Pa.

▲

The Crocker-Wheeler Electric Manufacturing Company, Ampere, N. J., has issued a 12 page booklet describing their various products. Alternating current polyphase induction motors, direct current motors, generators, motor generator sets, speed changers, flexible couplings, and torque meters are described in a most interesting manner. Write to Crocker-Wheeler for your copy.

▲

The Crouse-Hinds Company, Syracuse, N. Y., has just issued bulletin No. 2265, which describes Obround Condulets for threaded and threadless conduit. Cross-Hinds will be glad to mail this bulletin on request.

▲

The Brown Instrument Company, Philadelphia, Pa., in their catalog No. 6702 describe their new indicating recording and controlling thermometers and pressure gauges. This is a very interesting 80 page catalog and may be had by writing the Brown Instrument Company at Philadelphia.

▲

For protecting motor-driven and other types of rotating machinery from breakdowns due to overheated bearings, The Electric Controller & Mfg. Co., 2720 E. 79th St., Cleveland, Ohio, announce the EC&M Bearing Thermostat. These thermostats are particularly well suited for use in connection with automatic pumping stations, motor driven fans, automatic electric substations, conveyor systems, refrigerating machines, compressors, etc.

▲

The Bartlett Hayward Company, Baltimore, Md., announces a new light duty Fast's Light Duty Self-Aligning Coupling. This coupling was developed to meet the need for an inexpensive trouble-proof coupling for drives from 1 to 25 horsepower. The Light Duty Coupling retains all the features of their standard forged steel coupling except that the casting is made of die cast metal.

▲

A complete re-vamping of design is announced by the Republic Flow Meters Company, Chicago, Ill.,. The new engineering features of design are to be found in the method of assembling the actuating elements in the various reading instruments. The basic principle of operation is practically identical with the Republic Meters which have been serving industry for the past twenty-three years.

▲

Homestead Valve Manufacturing Company, Coraopolis, Pa., announces the advent of a new, fully-automatic model of the Hypressure Jenny, their high-powered machine for all purpose cleaning, paint-stripping, or sterilizing. The improved and simplified unit is termed the Model "D".

▲

A new cutting machine, known as the Oxweld Straight-Line Cutting Machine, has been added to the Oxweld line of welding and cutting apparatus by The Linde Air Products Company, 30 East 42nd Street, New York.

This machine consists essentially of a steel channel supporting base, a means for moving the blowpipe, and adjustments for setting the blowpipe to cut bevels. Motion in two directions is possible: 45 in. longitudinally and 7¾ in. laterally. The machine can be furnished either with two traverse hand-wheels for hand operation, or with one hand-wheel and a 110-115-volt universal motor, either of which can be used by simply throwing a lever.

▲

The General Electric Company has added 7600 employees to its payrolls since March 1, and the total annual payroll rate is today $17,000,000 greater than it was on that date, Gerard Swope, president, made known recently in a statement to the company's 187,000 stockholders mailed with regular dividend checks.

New business booked the first nine months of the year has shown a steady rise, and for the first time since 1929 orders have exceeded those for a like period of the previous year.

Another significant fact, Mr. Swope points out, is that this year, for the first time in three years, orders for the third quarter totaled more than the sales billed in the same period.

In referring to the N.R.A. President Swope declares General Electric has conformed not only to the letter but to the spirit of the Act and began operating under the Electrical Manufacturers Code, as to hours of employment and wages, a week before the code went into effect on August 15.

These requirements necessitated but little change in the company for the maximum work-week since May 1, 1931, has been only 40 hours and there were but few employes whose pay was at a lower rate than that prescribed by the code.

▲

"Farrel Gearflex Couplings" is the title of an attractive new bulletin, No. 437, describing the flexible couplings manufactured by the Farrel-Birmingham Company, Inc., 437 Vulcan St., Buffalo, N. Y.

The bulletin is 8½" x 11" to fit standard binders and files, and is done in two colors, with numerous illustrations, diagrams and tables of ratings, dimensions, weights and list prices, as well as complete descriptive matter and information for ordering or inquiring for "Gearflex" Couplings.

A copy of the bulletin may be obtained free on request to the company's office at Buffalo, N. Y.

ASSOCIATION NOTES

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Inspection Trip

While the association has closed its campaign for new uses for steel, it is still vitally interested in all developments which will increase its consumption. As an indication of the deep interest which the members have in new uses for steel over 175 members of the Pittsburgh district section, in conjunction with the Engineers society of Western Pennsylvania, visited the plant of the Westinghouse Electric and Manufacturing Company on November 10 to inspect the huge, welded steel gates manufactured by this company for the Boulder Dam project. The manufacture of these gates required a considerable tonnage of steel as well as a large amount of engineering skill. This example set by a prominent company should spur other manufacturers to use, wherever possible, rolled steel on projects of a similar or associated nature.

To further indicate the interest in a new use for steel the following steel mill executives recently inspected these gates:

F. B. Hufnagle, President of the Crucible Steel Company.

D. A. Barrett, Vice President of the American Sheet & Tin Plate Co.

J. W. Marriman, Vice President of the A. M. Byers Company.

C. H. Hunt, Asst. to President of the Weirton Steel Company.

R. E. Zimmerman, Vice President of the United States Steel Corporation.

G. G. Thorpe, President of the Illinois Steel Company.

C. C. Kimball, Vice President of the Illinois Steel Company.

J. J. Kennedy, Vice President of the National Tube Company.

Gordon Fisher, Chairman of Board of the Spang-Chalfant Company.

W. E. Watson, Vice President in Charge of Sales, Youngstown Sheet & Tube Company.

Frank P. Bell, President of the Edgewater Steel Company.

E. L. Benedict, Vice President of the Pittsburgh Steel Company.

C. W. Bennett, Acting President of the American Sheet & Tin Plate Company.

More than four million pounds of steel and special materials are required in the production of the world's largest valves and to ship them to the Boulder Dam will require about ninety railroad cars. A total of eight gates, two in each intake tower will control the flow of water to the power plant developing 1,835,000 horsepower. With the exception of the cast steel throat liner and the small deflection plates, each gate is fabricated entirely by arc welding from steel plate.

In accordance with the boiler code requirements for class two welding, eighty welders were trained for this job for which a special heavy coated welding rod was developed. Standard steel plate rolled, cut to size and welded from the thirty-two foot cylindrical gates and nose liners. Because of the size and the accuracy required, the welding and machining presented many unusual problems. Due to the carefulness with which the mammoth gates were fabricated, every piece fit into place with precision and a water tight seal was secured in the test assembly at the shops.

In the construction of the gates, over 4,600,000 pounds of materials were used including steel plate, steel castings, bronze, copper, stainless steel and monel metal. More than one mile of welding is used in the fabrication of one gate. Each gate assembly consists of a throat liner, a cylindrical valve, a nose liner, valve guides and minor fittings.

The throat liner, thirty-seven feet in diameter, is of cast steel, in twelve sections. The partings were machined on each section. Then the seats and faces were finished in position. Each nose liner is all welded and fabricated mainly from 2" and 2¼" steel plate hot formed on a 1500 ton press and fastened to the throat liner with 312 bolts. There are 28,200 inches of weld employing 252 positions of the sub and main assemblies to complete the welding on this largest stationary part of the gate. It is made in six sections bolted together. A total of 2,514 holes of various sizes are drilled in the liner for bolting on the guide rails, throat liner, seats and entrance liners.

The monel metal seats making the water tight seal between the gate valve and the throat and nose liners are very carefully machined, 110,000 pounds being used for that purpose. Adjusting screws are provided for obtaining a perfect seal and locking into position on the upper seat only of each gate.

The cylindrical gate valves weigh 240,300 pounds and are formed entirely from steel plates cold rolled and welded. Each is made in six segments. Seven stiffening ribs, cold rolled from 2¾" x 11¼" stock on vertical rolls exerting a pressure of 575,000 pounds, are welded in position in each valve. To prevent water turbulence steel plates will be bolted over these ribs on the lower gates only. Also, specially cast steel deflection plates will be placed atop the lower gates to prevent turbulence and wear at the top seat.

The entire lower gate including the stationary and movable parts weighs 523,858 pounds and will be placed in the base of one of the 340 feet towers with another gate 150 feet higher. At the base the towers are 95 feet in diameter. When finished, the dam will be the highest and largest ever constructed forming a lake 30,000,000 acre-feet or about 11,000,000,000,000 gallons, the largest artificial lake in the world.

A. I. & S. E. E. DISTRICT SECTION OFFICERS AND COMMITTEEMEN FOR 1933-1934

Chicago District Section

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Vice-Chairman: C. J. Smith, Electrical Engineer, Illinois Steel Company, South Chicago, Ill.

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W. J. Tunny, Testing Engineer, Youngstown Sheet & Tube Co., East Chicago, Ind.

J. F. Headlee, Testing Engineer, Illinois Steel Company, Gary, Ind.

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Secretary: W. W. Spanagel, Reliance Electric & Engineering Company, Cleveland, Ohio.

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L. Long, Asst. Elec. Supt., National Tube Company, Lorain, Ohio.

T. J. Ess, Combustion Engineer, Republic Steel Corp., Massillin, Ohio.

Birmingham District Section

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Vice-Chairman: C. R. Tinsley, U. S. Pipe & Foundry Co., Birmingham, Ala.

Executive Committe: W. J. Donahue, Electrical Engineer, Republic Steel Corp., Sayreton, Ala.

F. G. Cutler, Chief, Bureau of Steam Engineering, Tennessee Coal Iron and R. R. Co., Birmingham, Ala.

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Membership Committee: W. H. Gilbert, Mechanical Engineer, Tennessee Coal Iron & R. R. Co., Birmingham, Ala.

A. L. Freret, Chief Electrical Engineer, Tennessee Coal Iron & R. R. Company, Birmingham, Ala.

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THE **BUSS SUPER-LAG** FUSE

A. I. & S. E. E.—TWENTY-SIX YEARS OF ENGINEERING SERVICE TO THE IRON & STEEL INDUSTRY

Electric Motor Drives for Rolling Mills in United States and Canada

NUMBER OF A.C. DRIVES—NUMBER OF D.C. DRIVES—TYPE OF DRIVE

State	Firms No.	Plants No.	A.C. Drives		D.C. Drives		Drives Combined	
			Drives	H.P.	Drives	H.P.	Drives	H.P.
Alabama	5	7	49	133,950	15	29,450	64	163,400
California	3	5	33	39,450			33	39,450
Colorado	1	1	9	19,200	5	5,550	14	24,750
Connecticut	2	3	16	12,950			16	12,950
Delaware	1	1	2	5,000			2	5,000
Georgia	1	1	2	2,150	7	7,800	9	9,950
Illinois	12	15	45	60,090	88	174,840	133	234,930
Indiana	8	10	120	244,320	107	193,800	227	438,120
Kentucky	3	3	32	26,500	6	6,250	38	32,750
Maine	1	1	1	300			1	300
Maryland	4	4	35	69,050	10	38,400	45	107,450
Massachusetts	2	2	3	4,500	7	8,650	10	13,150
Michigan	5	5	20	32,900	49	70,500	69	103,400
Minnesota	1	1	5	13,100			5	13,100
Missouri	4	4	17	16,175	6	6,100	23	22,275
New Jersey	6	6	10	7,100	10	9,800	20	16,900
New York	13	14	71	67,900	29	91,800	100	159,700
Ohio	27	43	234	318,865	180	240,985	414	559,850
Oklahoma	1	1	1	1,200			1	1,200
Pennsylvania	27	58	224	274,980	170	246,640	394	521,620
Rhode Island	1	1	3	2,950	3	1,450	6	4,400
Tennessee	1	1	4	3,400			4	3,400
Texas	1	1	1	500			1	500
Virginia	1	1	2	485			2	485
Washington	2	2	5	6,200			5	6,200
West Virginia	4	6	30	40,550	29	31,450	59	72,000
Wisconsin	4	4	14	10,450	1	400	15	10,850
Total—U. S.	141	201	988	1,414,215	722	1,163,865	1,710	2,578,080
Canada	8	8	13	22,200	12	21,600	25	43,800
Totals	149	209	1,001	1,436,415	734	1,185,465	1,735	2,621,880

State	Firms No.	Plants No.	TYPE OF DRIVE						
			Direct	Geared	Coupled	Belt	Chain	Rope	Miscellaneous
Alabama	5	7	20	34	5			2	3
California	3	5	4	28					1
Colorado	1	1	5	9					
Connecticut	2	3	5	11					
Delaware	1	1		2					
Georgia	1	1	3	4					2
Illinois	12	15	53	65	3	4	5		3
Indiana	8	10	68	129	19			11	
Kentucky	3	3	2	36					
Maine	1	1		1					
Maryland	4	4	10	35					
Massachusetts	2	2	4	6					
Michigan	5	5	10	56	2				1
Minnesota	1	1	2	2	1				
Missouri	4	4	7	12			2		2
New Jersey	6	6	5	10	3	1		1	
New York	13	14	35	52	6	2		1	4
Ohio	27	43	100	282	5	6		18	3
Oklahoma	1	1		1					
Pennsylvania	27	58	139	187	36	1	2	15	14
Rhode Island	1	1	4	2					
Tennessee	1	1		4					
Texas	1	1		1					
Virginia	1	1		2					
Washington	2	2		2		1		2	
West Virginia	4	6	9	43	3			2	2
Wisconsin	4	4	1	10	3		1		
Total—U. S.	141	201	486	1,026	86	15	10	52	35
Canada	8	8	11	11	1			2	
Totals	149	209	497	1,037	87	15	10	54	35